Acknowledgements

This book should have been written long before today. We see it as a comprehensive text that builds on the pioneering 1958 and 1966 CAB works of Mahadevan, concerning Dairy Cattle Breeding in the Tropics and Breeding for Milk Production in Tropical Cattle. We also see it as a subject that will continue to rise in importance in the developing tropics. Smallholder milk production continues to involve increasing numbers of people providing a regular income to support families. In some cases, continued participation in the industry has been possible without ownership or tenure over land. The importance of milk as a dietary component in rural communities provides benefits above cash flow and income production and these nutritional benefits also flow into urban communities. For these reasons, we first wish to acknowledge the millions of smallholder milk producers throughout the tropics. These are the people whom we hope will be the ultimate beneficiaries of the work presented in this book.

We wish to thank sincerely the authors of the chapters that comprise this book. We initially made a conscious choice of the types of people whom we would invite to contribute. These included people who had demonstrated leadership in their fields and commitment to further assist smallholder dairy farmers, and who knew or knew of each other through their professional interests in the field. We also selected people across a wide range of countries and all continents to ensure that the examples used to explain practical points include the colour and variations that make up the diversity of smallholder dairying across the tropics. In thanking these authors, we also accept responsibility in editing and trust that we have faithfully represented the individual authors’ viewpoints and intentions. Specifically we thank the chapter authors: S. Aiumlamai, P. Bandyopadhyay, N.V. Belavadi, A.J. De Boer, P.N. de Leeuw, C. Devendra, A.R. Egan, B.K. Ganguly, D. Gilmour, L.R. Humphreys, S. Kumar, R. Leng, B. Malcolm, V.D. Mudgal, S.R. Na Phuket, I.M. Nitis, M.K. Niyogi, A. Omore, O. Perera, S.K. Ranjhan, H. Schelhaas, S. Staal, V.K. Taneja, T. Thirapatsakun, W. Thorpe, J.E. Vercoe, Alemu Gebre Wold and E. Zerbini.

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The generous support of the International Livestock Research Institute (ILRI) is also acknowledged with gratitude. From the outset, we were determined that the publication would be made available to the widest possible audience of progressive smallholders, teachers, academics, researchers, planners and others. The generous contribution of the ILRI in publishing and distributing the book has enabled us to achieve that objective.

Finally, we wish to acknowledge the contribution of our own institutions. From Charan’s perspective, the financial support of the Thailand Research Fund (TRF) through the TRF Senior Research Fellowship Project; also Kasetsart University and its continued support for animal-related development; and from Lindsay’s, the University of Melbourne for its commitments to international agriculture and to wider international involvement.

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Charan Chantalakhana. Refer to Editors section above.
Lindsay Falvey. Refer to Editors section above.
Foreword

Total consumption of milk in developing regions is projected to increase from 164 million metric tonnes in 1993 to 391 million metric tons by the year 2020 – a 138 percent increase! The expected increase in per capita consumption is from 38 to 62 kg/person. The triple effects of population increase, income growth and urbanisation will fuel this tremendous growth in demand.

Milk provides quality protein and essential micronutrients needed for nutrient balance in marginal diets based on staple grain and root crops. The production of more milk in developing countries will help meet the needs of urban families at prices they can afford. With affordable prices, poor families, especially children, are more likely to consume the quality protein and essential micronutrients they need for healthy physical and mental development.

Increasing dairy production is a major challenge for those engaged in international livestock development. Moreover, there are environmental concerns about livestock production in fragile landscapes, so increasing milk supply should be done in an environmentally sustainable manner. Research can help meet this challenge.

Meeting the growing demand for milk offers both a major opportunity and a significant challenge to the smallholder dairy farmers who predominate in developing countries. The importance of smallholder dairying in developing countries has too often been overlooked. Milk is a "cash crop" for smallholders; converting low value forages and crop residues, and using family labour into a valued market commodity.

Notwithstanding its importance, smallholder dairying has been poorly documented and understood. Professors Falvey and Chantalakhanh and the authors have done us all a service in providing this comprehensive document about smallholder dairying.

This volume covers the breadth of smallholder dairying with a mix of the practical aspects of interest to farmers and the scientific information needed by professionals interested in international development of smallholder dairying. It serves the needs of teachers and academics, advisors to the next generation of smallholder dairy farmers, scientists and the international development agencies concerned with technical issues and the social and economic benefits of dairying in the tropics.

This book results from productive collaboration among institutions and scientists in developing and industrial countries. The Thailand Research Fund (TRF) of the Prime Minister’s office, Thailand and Institute of Land and Food Resources of the University of Melbourne, Australia, joined with ILRI in supporting publication of the book. We thank the editors, the chapter authors, and all those who made this work possible. We trust that this book will help improve smallholder dairy production in the tropical world.

Hank Fitzhugh
Director General
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Chapter one
The dairy industry in a changing world
H. Schelhaas

Introduction

In many respects the dairy industry occupies a special position among the other sectors of agriculture. Milk is produced everyday and gives a regular income to the numerous small producers. Milk production is highly labour-intensive and provides a lot of employment.

The dairy industry is the sector with the highest degree of protection due to the economically vulnerable position of small milk producers. Milk - also known as white gold - can be used to make an enormous variety of high quality products. The high cost of milk as a raw material has necessitated a high-tech processing industry. The special nature of milk (perishable and bulky) leads to the necessity of strict and comprehensive quality regulation and to high transport costs. The large dependence of milk producers on the dairy processing industry has resulted in a strong position held by the co-operatives in milk marketing and in the processing industry.

The whirlwind of changes, which is passing through the world, is also exercising a growing influence on the dairy industry. The number of milk producers is falling rapidly, the dairy processing industry is becoming more and more highly concentrated, the international dairy markets are increasingly liberalised and are giving greater opportunities to low cost producers, including many from developing countries.

Four specific features of the dairy industry

The dairy industry has a number of specific features which distinguish it from the other sectors of agriculture in a number of respects. The dairy industry is a special case in world agriculture.
The specifics of the dairy industry are due to four, partly interrelated, factors. The first factor is to be found in the specific properties of milk as a raw material. Milk is basically a liquid consisting of 90 per cent water, which means that it is a bulky and heavy commodity; also, milk is produced on a daily basis. As a consequence, milk requires high-cost transportation and there is a cost limit on the range over which it can be sold. Furthermore, milk will only keep for a few days, which places a time limit on the period during which it must be used or processed and transformed into a more stable, longer keeping form. On top of that, milk is highly perishable and also potentially subject to adulteration, whilst the quality of the raw material is highly dependent on farm management. Strict and comprehensive quality regulations are therefore customary and necessary, and they are much more far-reaching and comprehensive than in other agricultural sectors.

The second factor distinguishing the dairy industry within agriculture as a whole is the socio-economic position of dairy farmers. The vast majority of them are small-scale producers, with a weak and vulnerable position on the market; the nature of the business (involving a high percentage of fixed costs) means that they are only able to adjust to market changes in a limited and gradual way. Furthermore milk is produced everyday and is a regular source of income to the numerous small producers. At the same time, milk production is a highly labour-intensive production and therefore provides many employment opportunities, not only in the dairy farming business itself but also in the transport and processing of milk and in the agricultural supplies sector. For that reason, in many countries the dairy industry is considered to be highly important for the liveability of rural areas. Due to this factor and its economically vulnerable position, in Western countries the dairy industry is far and away the sector with the highest degree of protection. More recently, in a number of countries dairy farming has come to be regarded as increasingly valuable in terms of nature and countryside conservation.

To an increasing extent, dairy farming is becoming multifunctional. In many European countries, dairy farming is more that a purely economic activity. An illustration of the special position of dairy farming in the rural community is a recent incident in Ireland. In that country, milk quotas were sold from the sparsely populated East of the country to the far more densely populated West, purely for economic reasons. The Irish Government considered this situation to be extremely undesirable for the liveability of the rural areas in the East, and made efforts to ban the sale of milk quotas from Eastern to Western Ireland. In another sector of agriculture, such an action would be unthinkable - and impossible.

The third factor highlighting the special position of the dairy industry is the strong position held by the co-operatives in milk processing. According to a survey by the International Dairy Federation (IDF) in 1984, in 21 countries, together accounting for 55 per cent of the world's milk supply, producer co-operatives marketed 86 per cent of the total sales of milk from farms. This was true, especially in Northern Europe (Scandinavia, the Netherlands, Germany), New Zealand and India where the co-operative milk processing industry is very strong, with the co-operatives often holding a share of over 90 per cent in the processing of milk. In the United States, in particular, the milk marketing co-operatives have succeeded in building up a strong position with a share of 80 per cent of milk supply vis-à-vis the dairy processing industry, which consists mainly of private enterprises.

The background to the strong position of co-operatives in the dairy industry can be explained by, on the one hand the strong dependence of small producers on the milk price and on the other hand by their weak position on the market. They are able to keep the milk for at most a few days and unlike grain producers for example, they are unable to defer selling their product until a more favourable moment on the grain exchange. As long ago as the 19th century, this led dairy farmers to want a direct influence on the processing industry, on which their livelihood was, and still is, so crucially dependent. The small family farm with such a vulnerable and difficult product as milk to market needs and assured outlet and a guarantee of a known price.
The fourth and final factor involved in the specific structure of the dairy industry is the fact that milk is a very valuable but at the same times an extremely expensive raw material. On the one hand, milk can be used to make a wide range of products which combine the features of being highly palatable, nutritious and at the same time high-quality. Indeed, milk is also known as 'white gold'. On the other hand, its high cost price includes the necessity of using milk to make products which have a high added value. The result is that the processing industry is very important to the dairy farming sector, far more important than in many other sectors of agriculture. In the dairy industry, the processing operations have to satisfy high technical and quality standards.

Over the years, the four above-mentioned factors have helped to form the very special position which, as stated above, the dairy industry today occupies among all the other sectors of agriculture. However, the great changes which are affecting the world as a whole are likewise leaving their mark on the dairy industry. The forces generated by these changes, such as the fast pace of technological progress, economic liberalisation, privatisation, scale enlargement, internationalisation and globalisation, are also exercising a growing influence on the dairy industry.

A whirlwind of change is passing through the world, and it cannot fail to have an impact on the dairy industry. For that reason, the lines which originated in the past cannot simply be extrapolated directly into the future; the nature of the dairy industry is undoubtedly heading for changes in the years ahead.

This chapter begins with a description of the current developments in the following spheres:

- milk production in Western countries, Eastern Europe and developing countries
- the milk processing industry
- dairy policy
- consumption of dairy products
- the international dairy market.

The chapter continues with a (cautious) review of specific features of the dairy industry which may also be valuable in the future and may potentially continue in existence.

**Milk production**

**Developments in western countries**

In the countries of the Western world (contrary to Eastern Europe) the family farms continue to dominate the dairy farming scene. However, particularly in recent years, a strong trend towards larger farms has emerged. Thus, in many European countries a drastic reduction has taken place during the past decade. In France, the European Union's biggest producer, as well as in countries like Denmark, Belgium and Finland their numbers have been more than halved in the course of the past ten years. In the United States, the last decade has witnessed a fall of 35 per cent in the number of dairy farms. In 22 Western countries and in Japan combined, the number of dairy farms has gone down by 1.2 million, from 2.7 million to 1.5 million. Only in New Zealand, where a rapid expansion of milk production is taking place, is the number of dairy producers' stable to slightly increasing.

Noteworthy in the United States, is the regional shift in production, away from the traditional producing states (Wisconsin, Minnesota) in the colder northern part of the country, towards the west and the south-
west (California, Washington, Texas), where the climate is subtropical. In 1993, for the first time, more milk was produced in California than in Wisconsin. In addition, an expansion of large-scale, low-cost dairy operations, with 1000 to 3000 dairy cows and more, can increasingly be seen taking place at the expense of small-scale dairy farms with their relatively high cost levels. It may be noted that many of the large-scale dairy farms, with cheap hired labour, continue to be run as family businesses.

In spite of the rapid decline in the number of dairy farmers, the average business size, in terms of cows per farm, is still relatively small, at least in Europe. This is illustrated by Table 1.1 showing the average herd size in a number of Western countries.

The situation in Eastern Europe

The situation in Eastern Europe is quite different from that in the Western countries. After the about-turn in Eastern Europe in 1989, the command economy was replaced by a free market economy. This has brought about a gigantic conversion process, also in dairy farming. The large collective dairy farms have been or are scheduled to be privatised. Many have already been split up into smaller privatised farms. In addition, a large number of very small farms have been formed, accounting for only a few per cent of the total production. These are too small to remain viable in the longer term.

Table 1.1. Average herd-size in a number of countries.

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<tbody>
<tr>
<td>Germany</td>
<td>15.6</td>
<td>25.7</td>
<td>26.5</td>
</tr>
<tr>
<td>France</td>
<td>17.4</td>
<td>31.1</td>
<td>31.0</td>
</tr>
<tr>
<td>Italy</td>
<td>9.5</td>
<td>20.1</td>
<td>21.3</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>40.8</td>
<td>45.5</td>
<td>45.9</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>59.4</td>
<td>71.0</td>
<td>72.9</td>
</tr>
<tr>
<td>Denmark</td>
<td>29.1</td>
<td>49.6</td>
<td>51.6</td>
</tr>
<tr>
<td>Canada</td>
<td>39.2</td>
<td>49.6</td>
<td>52.0</td>
</tr>
<tr>
<td>United States (1992)</td>
<td>42.0</td>
<td>61.8</td>
<td>74.1</td>
</tr>
<tr>
<td>Australia (1990)</td>
<td>93.7</td>
<td>132.2</td>
<td>138.4</td>
</tr>
<tr>
<td>New Zealand (1990)</td>
<td>152.0</td>
<td>201.4</td>
<td>214.5</td>
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</tbody>
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The process of transition is accompanied by great uncertainties, partly due to the unclear and uncertain economic and political situation and also to the inappropriate dairy policy. The dairy policy is mostly too liberal, thereby leading to destabilisation and to low milk price. A lack of capital for the badly needed modernisation is another factor. As a result, milk production has decreased substantially in the past few years (Table 1.2).

Table 1.2. Milk production in Eastern Europe (‘000t).

<table>
<thead>
<tr>
<th>Year</th>
<th>(Index 1990 = 100)</th>
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<tbody>
<tr>
<td>1990</td>
<td>100</td>
</tr>
<tr>
<td>1994</td>
<td>76</td>
</tr>
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http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap1.html
The outcome of the revolutionary process is extremely important, but difficult to predict. It remains to be seen whether the privatised, often split up, collective farms will be sufficiently viable in the longer term. For the present, many of them are experiencing a financial crisis, and their milk production is declining sharply. Even in Eastern Germany, where a lot of capital was available for the purpose of restructuring, far more than in the other Eastern European countries, the split-up, privatised dairy farms are not yet successful in all respects. No lessons can yet be learned from developments which have taken place so far; that may take quite a few years. It is possible that the dairy farming sector in Eastern Europe may remain stagnant for many years to come. Possibly, in most countries a structure will emerge like that which exists in Eastern Germany. There the large collective farm enterprises have been privatised into smaller-scale businesses, but where large dairy herds with several hundred milk cows have nevertheless continued to exist and where modern small-scale private farms are being set up to a limited extent at present with a share of not more than 10 per cent of total milk production.

At a recent IDF symposium in Warsaw (24-26 October 1994) the following conclusions were drawn with reference to the situation in Eastern Europe:

- Milk production and production of most dairy products are still following a downward slope, but the angle of the slope has diminished. Consumption of dairy produce is showing signs of recovery in some countries.

- Bad structural conditions for milk production and production of dairy products are giving rise to increasing protection of the domestic markets and government intervention, to some degree.

- Privatisation is certainly the key factor in the agricultural reform process. Uncertainty with respect to land property is paralysing production in agriculture. Because of its tradition of a largely private agricultural sector, Poland is still the exception to the rule that the agricultural sector remains subject to continued decapitalisation in most countries.

- In general, it may be concluded that the complexity of the reform processes has been underestimated. In 1990, 'experts' in Central and Eastern Europe and in Western countries alike expected that within five years some countries would be EU member states, that most state enterprises would have been privatised, that the transition to a market economy would to a large extent have been completed and that some currencies would have been made convertible. Almost five years later, none of these expectations has been fulfilled, but still the same optimistic expectations can be heard. The conclusion has to be that there is still very little knowledge about the complicated process of switching a centralised economy to a market economy.

**The structure of dairying in developing countries**

From the historical viewpoint, the origin of dairying lies in the developing countries, in Mesopotamia to be precise, at around 6000-7000 BC. From this region, milk production and milk consumption spread to other regions in Europe, North and East Africa, and Asia. The developing countries can be divided into traditional and non-traditional milk producers. Traditional milk-producing regions are, roughly, the countries of the Mediterranean and the Middle East, the Indian subcontinent, the Savannah regions of Western Africa and the Highlands of Eastern Africa, and to some extent South and Central America. Further, the consumption of milk and dairy products played an important role among the nomads in Africa and Asia.
The majority of the humid regions, South East Asia, China, Korea, and Japan, account for the non-traditional milk-producing countries. Nevertheless, for example in China, milk was regarded as very beneficial for the ill and the elderly.

In the 'traditional' milk-producing regions in Asia and also partly in Africa, the structure of milk production is characterised by small farms with not more than three or four animals. Dairying there is nearly always part of a mixed farming system. The dairy cattle are often used as draught animals as well. Livestock are fed principally on agricultural residues and waste, and are grazed on natural pastures of non-arable land. Cattle husbandry and milk production is largely supported on the by-products of agriculture. In this way, a nutritionally superior product is produced in an ecologically and environmentally favourable way.

In Central and South America, the scale and design of dairying are medium, with mixed beef and dairy operations. The average milk production per cow is higher than in the regions mentioned above, at about 1000 kg per year, but it ranges from 1400 kg to 1900 kg in Chile and the Eastern part of the Argentine, the whole of Uruguay, and the Southern part of Brazil. Nevertheless, here too the small producer also plays an important role. Estimates indicate that in the majority of the Latin American and Caribbean countries between 60 per cent and 80 per cent of the milk producers can be classified as small-scale producers, accounting for 25 to 30 per cent of milk production in these countries.

In the 'non-traditional' milk-producing countries the structure of dairying is more varied. Especially in the tropical and subtropical regions, besides small farms there are also large-scale specialised dairy farms, sometimes with several hundred cows or more, most of which were founded in colonial times or after the Second World War.

In the economies with a centrally planned history, there are often still large-scale capital-intensive and specialised state farms, for example in Cuba, China, Ethiopia and Tanzania. Saudi Arabia, for instance, also has large-scale dairy farms with up to several thousand dairy cows.

Summary and conclusions

In the Western countries, the number of dairy cows per farm is increasing rapidly but the average dairy herd remains relatively small. In European countries the family farm specialising in dairying continues to be the most common form of business. This is similar to Australia and New Zealand, however the average farm size in these countries is greater than 100 dairy cows (about 120 and 180, respectively). Especially in the few subtropical states of the United States are farms with over 1000 dairy cows gaining ground.

Eastern Europe is engaged in a drastic transitional process; the large collective farms have been privatised and usually divided into smaller units, while a large number of very small private farms are also emerging which in the long run will not be viable. At the present moment, the future structure of the dairy industry there is unclear.

In the developing countries the small mixed farm predominates. In Africa and Asia dairying is nearly always part of a mixed farming system, with, in most cases, no more than three or four dairy cows. In South America the scale of the operations is larger (10 or more dairy cows) with mixed beef/dairy operations.

The processing industry in Western countries

Towards bigger dairy enterprises; a somewhat weaker position of the dairy co-
The dairy industry in a changing world

The processing industry is experiencing the effects of scale enlargement and rationalisation to an extent far greater than dairy farming. The Dutch dairy industry, in the late 1950s, still had 530 small local dairies. Since the beginning of 1998, there are no more than 13 dairy enterprises; two major enterprises process the total milk deliveries (about 80).

The situation in most other European countries is more or less the same (Table 1.3). In all Western countries, the concentration process is making rapid advances in the dairy processing industry. In France, the four major enterprises (Besnier, Bongrain, Sodial and Entremont) control more than 50 per cent of the national dairy processing industry as against only 20 per cent one year before. Only one of those enterprises (Sodial) has a co-operative structure. France's largest dairy processor handles more milk than the total production of countries such as Ireland or Portugal. In Australia the two biggest dairy co-operations have a share of 40 per cent of total milk production.

**Table 1.3. Europe’s top fifteen dairy groups (1997).**

<table>
<thead>
<tr>
<th>Dairy group</th>
<th>Milk processed (m. lit.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friesland Coberco</td>
<td>6100</td>
</tr>
<tr>
<td>Campina Melkunie</td>
<td>5200</td>
</tr>
<tr>
<td>Besnier</td>
<td>5000</td>
</tr>
<tr>
<td>MD Foods</td>
<td>3700</td>
</tr>
<tr>
<td>Avonmore Waterford</td>
<td>3300</td>
</tr>
<tr>
<td>Bongrain/ CLE</td>
<td>3200</td>
</tr>
<tr>
<td>Nestle</td>
<td>2800</td>
</tr>
<tr>
<td>Sodiaal</td>
<td>2400</td>
</tr>
<tr>
<td>Arla</td>
<td>2100</td>
</tr>
<tr>
<td>Danone</td>
<td>2000</td>
</tr>
<tr>
<td>MZO</td>
<td>1800</td>
</tr>
<tr>
<td>Valio</td>
<td>1600</td>
</tr>
<tr>
<td>Nordmilch</td>
<td>1600</td>
</tr>
<tr>
<td>Northern Foods</td>
<td>1500</td>
</tr>
<tr>
<td>Unigate</td>
<td>1400</td>
</tr>
</tbody>
</table>

In both Denmark and Sweden, the biggest dairy enterprise (MD Foods and Arla, respectively) account for over 60-65 per cent of national milk production. Almost all the above-mentioned dairy enterprises have taken their first steps towards internationalisation of their business. The French enterprises have operations *inter alia* in Spain, Belgium and Luxembourg, the Dutch dairy enterprises have operations in Belgium, Germany, the Far East and the United States, and MD Foods operates in, for example, the United Kingdom and Germany.

In Germany and France, the position of co-operative milk processing may be described as having been weakened. In the Scandinavian countries, New Zealand and the Netherlands, the co-operative forms of
dairy processing remain dominant, with a share of 90 per cent or more in the dairy processing industry, although its structure is also changing.

Organisational changes

In a number of European countries, the structure of the National Dairy Organisations has been modified to reflect the structural changes which have taken place in the processing industry. For instance, in Sweden, Denmark, the Netherlands and France the influence of the big dairy processors on the national dairy institutions, for example, research institutes, has become dominating. In France and the Netherlands there has also been a merger between the private and co-operative dairy industry organisations. Substantial staff cuts have been made in the national dairy organisations.

In the United Kingdom, the venerable Milk Marketing Board has been disbanded and replaced by a private organisation, Milk Marque. Its functions are far less comprehensive than those of its predecessor. Milk Marque may be regarded as a national milk-purchasing co-operative; it will sell the collected milk to dairy processors. It is noteworthy that the Milk Marketing Boards of South Africa and Zimbabwe, which are broadly modelled according to their British counterpart, have also been reorganised and now have considerably fewer powers. The South African Milk Marketing Board today performs what is mainly an administrative function, for example, gathering dairy statistics.

The trend towards scale enlargement is expected to increase, and more trans-border mergers are expected to take place. Nevertheless, there will also remain room for small-specialised dairies, for example producing high-quality products or specialities, and producing for local markets. It is expected that the big dairy co-operatives will become more dominant.

Dairy policy

Towards less protection

As stated above, the dairy industry is the sector which has the highest degree of protection. However, the forces which are acting towards change, such as internationalisation and privatisation are growing increasingly powerful, and are pounding harder on the doors of the protected dairy industry.

At present, almost all Western countries operate intervention systems, which support their domestic dairy prices and stabilises the markets. In this way domestic markets are sheltered from the world market. Moreover, in its milk quota system, the European Union has an effective system which regulates the
Moreover, in its milk quota system, the European Union has an effective system which regulates the quantity of milk production. The United States applies a far-reaching organisation of the liquid milk market. Only Australia and New Zealand have an almost completely free market economy in the dairy industry. This is not so much for ideological reasons as because the cost price of milk in these countries is so low as to make market protection unnecessary. Nevertheless, over the past few years the level of protection has been gradually reduced both in the EU and in the USA. In recent years the EU has experienced a slight downward trend in milk prices. In the USA the federal support price has decreased by 10 per cent over the past decade in a period in which the inflation rate was fairly high (about 50 per cent) which means that in real terms the reduction was much bigger.

**The GATT agreement**

The signing of the recent GATT agreement represented a major breakthrough on the road towards a free world dairy market. This agreement will lead to a reduction in the level of domestic market protection, a lowering of export subsidies and hence to an enlargement of the scope for imports. Table 1.4 summarises the GATT decisions on agriculture for the period from 1995 to the year 2000.

**Table 1.4. Summary of GATT decisions (1995-2000).**

<table>
<thead>
<tr>
<th>General support</th>
<th>A reduction of 20 per cent; for developing countries: 13 per cent over 10 years.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports</td>
<td>Thirty-six per cent reduction of import duties over 6 years; for developing countries 24 per cent over 10 years;</td>
</tr>
<tr>
<td></td>
<td>A minimum market access of 3 per cent of internal consumption in the reference period 1986-1988 in the first year, rising to 5 per cent in 2000.</td>
</tr>
<tr>
<td>Exports</td>
<td>Developing countries, 24 per cent over 10 years;</td>
</tr>
<tr>
<td></td>
<td>Twenty-one per cent reduction of the subsidised export volume, for developing countries 14 per cent.</td>
</tr>
</tbody>
</table>

It may be noted that, for importing developing countries, the effect of reduced export subsidies, and higher world market prices, may partly or wholly be cancelled out by the obligation incumbent on those countries to reduce their export duties. In developing countries, these duties are sometimes high and are also levied on the value of the end products. Therefore, reduced export subsidies need not necessarily lead to higher prices for dairy products on the domestic market in a developing country.

**Effects of the GATT agreement may be as follows:**

- The EU’s share in the world dairy trade (excluding intra-EU trade) may decline from about 50 per cent now to around 35 per cent in 1999.
- In the short term, a rise in the order of magnitude of 25 per cent for cheese and whole milk powder, whereas there will be a far lower impact on the price levels of other products.
- In the longer term, a levelling of the increase in cheese prices and an overall improvement in price levels on the international dairy markets of about 10 per cent to 15 per cent.

The next GATT round is envisaged to start in the year 1999. It is expected that, in principle, the lines of the recent GATT agreement will be pursued strongly. This includes a further reduction of protection,
especially a lowering of the export restitution and a liberalisation of dairy imports.

**Future expectations**

It is not to be expected that Europe will be willing to abandon its present dairy policy within the foreseeable future. An important factor is that in the recent GATT agreement the principles of the present EU agriculture policy were accepted as being in accordance with the principles of the GATT agreement.

For the EU dairy policy, it is a matter of great importance whether the milk quota system is to be retained. At any rate it has been decided that the system is to continue until the year 2006. At the moment there is still a powerful current of thought in favour of not abandoning the market stability which the quota system has created in the short term.

In the United States, the movement towards a phase-out of agricultural protection and towards the free market in agriculture as well is much more powerful than in Europe. In the debate on dairy policy, the question is currently being asked whether the present intervention system is in fact still needed. The chance of the protection of the dairy industry being totally abolished in the coming years is much greater in the US than in Europe. Accordingly, present intentions are that the price support system in the United States will be abolished in the year 2000.

The following developments may be expected for the years to come:

13. gradual further liberalisation of the dairy markets

14. gradual further reduction of the level of domestic protection

15. retention for many years to come of the principles of the present European dairy policy (based on milk quotas and an intervention system).

It should be noted that any forecast is difficult even in a general way, and the more so when it comes to political developments.

**Consumption of dairy products in Western countries**

**Structural changes in the food market; general trends**

The general trends in the food markets in the Western countries may also be relevant to the more prosperous markets in the other parts of the world. This is because the world is increasingly becoming a `global village' and the trends in the Western countries may be similar in other parts of the world. This development is referred to as `triadisation', meaning the economic, socio-cultural and technological integration process of those most highly developed parts of the world, Japan plus the economic 'tigers' in South East Asia, Western Europe and North America. Nevertheless, despite general trends holding true for the market as a whole, the food markets in every continent and every country continue to have their own specific characteristics.

The food markets in Western countries are in constant motion. In recent years, major changes have taken place, such as socio-demographic changes (including many more single person households and small families), the disappearance of traditional eating habits, a more multiracial society, more eating out, higher priorities for health and freshness, and greater demand for food produced in an environmentally friendly way.
Changes in emphasis in the above picture and new developments in the 1990s may be as follows:

16. A shift away from choosing by appearance towards choosing for quality. For food, this will mean that special attention is given to its composition.
17. Health will become an even more important factor, subdivided into the following elements: ingredients, appreciation of freshness, nutritional value and purity.
18. Consumers will maintain or even intensify their efforts to reduce fat consumption.
19. Across the board there will be a growing aversion to things synthetic: purity becomes the symbol of the 1990s.
20. There is an even greater willingness to try out new products; the life-cycle of products becomes shorter, also due to the further individualisation of society.
21. The trend towards convenience will continue even more strongly; there is a future for table ready products.

Of all these trends, purity is the main one. Purity will be the symbol of the 1990s.

**Recent trends in the consumption of dairy products**

For many years, in Western countries the consumption of butter has been falling, that of liquid milk has remained unchanged or decreased slightly, while cheese consumption has increased.

The situation differs from country to country. In countries with liquid milk consumption figures below 100 kg per year, liquid milk sales have been increasing, whereas in countries where consumption is higher than 100 kg per head, the liquid milk market has been declining.

In recent years, many countries have experienced a strong improvement in the healthy image of milk fat (Canada, the United States, the Netherlands, Germany). The link which had previously been assumed to exist between the consumption of milk fat and the incidence of cardiovascular disorders has been largely disproved as a result of recent research. According to recent findings, butter has no adverse effect on cholesterol level; in addition, it is a pure, natural product with a superior taste.

In several countries, the market for dairy products is characterised by polarisation, and is moving towards the extremes of premium/branded high-quality products on the one hand and low-price products on the other. The middle ground is shrinking. The consumption of imitation products is declining; in most European countries, their share of overall consumption is minimal.

Noteworthy is the strong decline in home deliveries of liquid milk in the United Kingdom: from 80 per cent five years ago to less than 35 per cent in 1997. This represents substantial erosion of the influence of the last bastion of home deliveries.

Major trends in food markets are, more demand for added value products, for food produced in an environmentally friendly way and a higher priority for freshness. In several countries the markets for dairy products is recently moving towards the extremes of premium/branded high-quality products on the one hand and low-priced products on the other. Food markets will remain in constant motion and the life cycle of products will become shorter. The markets of the individual countries all have their own characteristics.
The international dairy markets

Global developments

The international trade in dairy products expressed as a percentage of total milk production is fairly small at around five per cent (including intra-EU trade). Since 1980, the total volume expressed in terms of milk equivalent has remained more or less unchanged, as shown in Table 1.5.

Table 1.5. Total exports of dairy products (excluding intra-EU trade) (in million tonnes of milk equivalent).

<table>
<thead>
<tr>
<th>Year</th>
<th>On solids non-fat basis</th>
<th>On fat basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>24.3</td>
<td>29.9</td>
</tr>
<tr>
<td>1985</td>
<td>25.2</td>
<td>28.8</td>
</tr>
<tr>
<td>1990</td>
<td>20.8</td>
<td>24.3</td>
</tr>
<tr>
<td>1991</td>
<td>22.7</td>
<td>29.6</td>
</tr>
<tr>
<td>1992</td>
<td>23.4</td>
<td>26.6</td>
</tr>
<tr>
<td>1993</td>
<td>24.3</td>
<td>29.8</td>
</tr>
</tbody>
</table>

It is clear that the markets for cheese and whole milk powder are growing whilst exports of the other products are either stagnating or falling. This trend is very likely to continue in the coming years. A stronger demand for cheese is expected to occur in Japan, South East Asia and the Middle East.

In contrast to the development in total dairy exports, the development of individual dairy product exports has tended to vary widely, as Table 1.6 shows.

The increased demand for whole milk powder will originate mainly from, once again, South East Asia, Central and South America, Brazil, Venezuela and the Middle East. Whole milk powder is used in a variety of end uses, but is often sold in insanitised forms in consumer packs for retail sale in countries which lack widespread refrigeration. The future of butter exports depends above all on the further developments in Eastern Europe, in particular Russia, which in the 1980s accounted for 35 to 40 per cent of world butter imports; these, however, have decreased strongly in recent years. It does not appear likely that butter exports to Eastern Europe will recover in the near future to reach the level of the 1980s.

Table 1.6. Development of dairy exports per product.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese</td>
<td>+16 per cent</td>
<td>+28 per cent</td>
</tr>
<tr>
<td>Whole milk powder</td>
<td>+30 per cent</td>
<td>+60 per cent</td>
</tr>
<tr>
<td>Butter</td>
<td>-19 per cent</td>
<td>+11 per cent</td>
</tr>
<tr>
<td>Skimmed milk powder</td>
<td>-14 per cent</td>
<td>-16 per cent</td>
</tr>
<tr>
<td>Condensed milk</td>
<td>-53 per cent</td>
<td>-37 per cent</td>
</tr>
</tbody>
</table>

1. Provisional figures.
2. The large fluctuations are attributable to the
irregular movements in butter imports, especially into Russia.

**Milk price levels throughout the world and the impact on future world trade**

The prices of milk in the various parts of the world differ rather widely, as Table 1.7 shows. It is to be expected that milk prices and milk production in the countries with a high milk price will come under pressure in the years to come. According to a recent OECD report dairy support prices in the OECD countries will fall by 15 per cent to 20 per cent over the next five years.

<table>
<thead>
<tr>
<th>Country/region</th>
<th>US$/100 kg (1993)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU (The Netherlands, Denmark)</td>
<td>40-42</td>
</tr>
<tr>
<td>EU (average)</td>
<td>36</td>
</tr>
<tr>
<td>USA</td>
<td>28.5</td>
</tr>
<tr>
<td>Japan</td>
<td>75</td>
</tr>
<tr>
<td>Argentina</td>
<td>15-20</td>
</tr>
<tr>
<td>Israel</td>
<td>34</td>
</tr>
<tr>
<td>South Africa</td>
<td>16-20</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>15-12</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>15</td>
</tr>
<tr>
<td>Switzerland</td>
<td>65</td>
</tr>
<tr>
<td>New Zealand</td>
<td>15-20</td>
</tr>
<tr>
<td>Australia: Manufacturing milk</td>
<td>22</td>
</tr>
<tr>
<td>Market milk</td>
<td>42</td>
</tr>
</tbody>
</table>

1. Since 1993 milk prices have not changed very much.

In summary, a noteworthy aspect of the development over the past decade has been the growth in the exports of cheese and whole milk powder, whilst there has been a decline in butter, skimmed milk powder and condensed milk. The total volume of world trade in dairy products remained about the same. It is to be expected that in the coming years there will be a decline in milk production in those countries where prices are relatively high, and that milk production will go up in countries with relatively low prices. The same applies to dairy exports from the various countries. This means that EU dairy exports may be expected to fall further, from 50 per cent to 35 per cent by the year 2000, while at the same time exports from Australia and New Zealand, currently 10 per cent and 20 per cent, respectively, will rise to reach perhaps 15 per cent and 25 per cent, respectively. Exports by developing countries for example, Argentina, Uruguay and India, are also heading for potential increases.
Conclusions

At the beginning of this chapter, it was stated that the dairy industry occupies a special position in four areas. The special nature of milk as a raw material (bulk, and to be produced every day) leads to high transport costs and the necessity of comprehensive and strict quality regulations. The great importance of dairy farming to the liveability of rural areas and the economically vulnerable position of small milk producers has been responsible for the high degree of protection. The large dependence of milk producers on the dairy processing industry has resulted in strong co-operatives in the milk marketing and milk processing sectors. The high cost price of milk as a raw material has necessitated a high-tech processing industry.

The whirlwind of changes which is passing through the world, however, is not failing to have an impact on the dairy industry as well, and that explains why the lines from the past cannot simply be extrapolated into the future direct. For the years to come we may expect the following possible developments:

Milk as raw material

Technological progress, for example, cooling, cheaper transport, will ease the transport problems slightly though not fundamentally. In coming years it will remain necessary for milk to be collected several times weekly. It is only for the very large dairy farms, with 1000 cows or more, that the transport problems are relatively less weighty.

The quality regulations, already far more comprehensive than in other agricultural sectors, are tending, if anything, to become stricter rather than weaker; in integrated quality management, that is, the control of quality from the producer right up through to the consumer, the large food retailers will come to exert a very large degree of influence.

The co-operative nature

The influence of co-operatives is diminishing in a number of countries, while at the same time the structure of co-operatives is undergoing changes. However, in the 21st century it will continue to be very much in the interest of small dairy farmers for strong co-operatives to be maintained and/or built up alongside a vigorous private processing industry. Especially because of the specific properties of milk as a raw material, the position of small producers on the market remains economically weak vis-à-vis the dairy processing enterprises, which are engaged in a strong concentration process, and vis-à-vis the giant multiple retailers.

The high degree of protection

The waves of modern times, liberalisation, privatisation, more market less government, run highest here. As a result of the recent GATT Agreement, reduced levels of protection, especially in all the Western countries, are to be expected in the coming years, and this will very probably lead to lower milk prices especially in Europe. However, it is not anticipated that a full transition to a free market economy in the dairy sector will occur, certainly not in Europe in the short term and it is not advised. For building up a sound dairy industry a stable and remunerative price level is highly desirable. Experience in Eastern Europe is clear in this respect: the introduction of a totally free market shortly after the about-turn, as in Poland, has resulted in unrest and instability and has also hampered the development of the dairy industry. In a general way it may be stated that the government has an important role to play during the build-up period of an economy; consider for example the experience in the NICs, and the reconstruction of the
economies in Western Europe after the Second World War.

**Manufacturing industry**

In the interest of dairy farmers, it is necessary for milk, a relatively expensive raw material, to be processed into a wide range of high-quality produces with high added value. A prerequisite for the processing industry is advanced technological know-how. The concentration process is going to continue in the years to come, and it seems likely that, in time, multinational co-operative enterprises will also emerge.

A number of other potentially important factors in the coming years include the following:

World market prices will probably start to rise in the next few years, partly as a result of the GATT Agreement; countries with low milk prices, including most developing countries, will be able to enlarge their milk production and possibly their dairy exports in this period; the expanding dairy market can create extra job opportunities leading to productive employment for the numerous small milk producers in developing countries.

If food markets in developing countries become subject to the same food market trends which prevail in Western countries, the dairy industries in developing countries will have to expect on the one hand an enlargement of the range of low-priced dairy products and on the other, an enlarged market for specialities. Purity, health, quality and convenience may become key factors in the marketing of dairy products. Bearing in mind the sometimes explosive rise in purchasing power in certain emerging markets, such as that in south and South East Asia, expansion of the dairy farming sector and the dairy processing industry is entirely feasible. A fair degree of optimism is warranted as to the prospects of the dairy industry in developing countries in general.

**Suggested reading**


Introduction

Ruminant livestock are a major component of agricultural systems in tropical countries. In smallholder systems, which dominate tropical agriculture, ruminants are important because they produce much more than food: they provide direct cash income; they are capital assets; they produce manure for use as fertiliser and fuel; and they may be a source of power for transport and cultivation. Nevertheless one function, the production of milk for human food, is often the primary reason for keeping livestock, whether by pastoralists to meet their subsistence needs in arid and semi-arid regions, or by peri-urban smallholder farmers as a source of income from milk sales.

Dairy production is a biologically efficient system that converts large quantities of roughage, the most abundant feed in the tropics, to milk, the most nutritious food known to man. As Walshe et al (1991) pointed out, where there is access to a market, dairying is preferred to meat production since it makes more efficient use of feed resources and provides a regular income to the producer. It is also more labour intensive and supports substantial employment in production, processing and marketing. Higher levels of production than those achieved in traditional tropical systems, whether from buffalo, cattle, camels or small ruminants, often require the introduction of specialised dairy breeds and increased levels of inputs (nutrition and health care) and good linkages to markets, both for milk sales and input acquisition. Thus, the intensification of smallholder livestock systems through the adoption of dairy production is generally concentrated in areas with good infrastructure close to major markets, although less intensive production may occur in other, more distant areas (Walshe et al 1991). These market factors, therefore, play a major part in determining the type of dairy production systems found in the tropics, and they are particularly important influences on smallholder dairy development.
The challenge represented by the expanding demand for milk and dairy products in tropical countries is great, and the resultant opportunities for smallholders are large. The world's human population is expected to increase from 5.4 billion in 1990 to approximately 7.2 billion in 2010. Most of the increase will be in tropical developing countries, where there will be a marked shift from rural areas to urban centres, with major shifts in patterns of food production, marketing and consumption. In Latin America and the Caribbean (LAC), for example, total milk production has increased by approximately two per cent per year since 1976, yet it has failed to keep up with human population growth. Tropical LAC produced 88 per cent of its milk requirements during 1984-91; by the year 2000 it is estimated that the deficit will be nine million tons (Ser 1990).

The lag in the domestic supply of milk relative to demand in the tropics has resulted from several factors. On the demand side, rapid increases in per person income, especially in Southeast Asia, urbanisation and high-income elasticity's of demand have fuelled increases in consumption. On the supply side, low animal productivity, inappropriate technologies, inadequate research and extension support, poor infrastructure and unfavourable external conditions have contributed to the poor performance of the livestock sector in general, and of the dairy sub-sector in particular (Williams et al 1995). Until recently many national policies made imported dairy products more available and affordable than domestically produced equivalents, but structural adjustment programmes in, for example, sub-Saharan Africa, have improved the incentives for domestic agricultural and dairy production (Staal et al 1997b).

Despite these changes, the volume of global milk output has not changed markedly over recent years because of counterbalancing forces: the substantial growth in milk output in Asia, Latin America and Oceania has been offset by a steep decline in output in Eastern Europe and the former USSR (Griffin 1997). During the next ten years, strong growth of milk production is expected in Asia and Latin America, where consumption is growing fastest, with global trends resulting in a shift in the balance of milk production away from developed to the developing countries. By 2000, developing countries are expected to account for 40 per cent of world milk production, a share which is expected to grow further (Griffin 1997). This shift will increase the importance of milk other than that from cows; while 99 per cent of the milk output of the developed countries comes from cows, almost one third of milk production in the developing countries comes from buffalo, goats, camels and sheep. Buffalo milk, for example, accounts for approximately half of the 67 million tons of milk produced in India each year (Aneja and Puri 1997).

The increased demand for milk and dairy products in the tropics, where low-income groups dominate the market, is expected to favour the informal market, particularly where milk is produced primarily by small- and medium-scale producers. In all such regions, the success of the informal market is based on consumer reluctance to pay the extra costs of pasteurisation and packaging. In Nicaragua, for example, the modern processing sector handles less than 40 per cent of total milk production; the remainder is marketed through the informal sector where approximately half is sold as unprocessed milk, 40 per cent is used for cheese and the rest mainly for cream, butter and fermented milk. The informal sector is growing more quickly because of the higher returns if the farmer produces cheese on the farm or sells milk to vendors or small-scale processors (Anon 1997).

In general, therefore, dairy production systems in the tropics are concentrated near consumption centres. It is no coincidence that cattle and rural human population densities are highly correlated (Kruska et al 1997), with specialised smallholder (and large scale) dairy farms generally located close to (peri-urban) or within (intra-urban) major markets, or more distant when there is an efficient market infrastructure. On the other hand, the systems of production and their productivity are influenced by agro-ecological factors and traditional consumption habits.

Global overview of tropical dairy production

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap2.html#TopOfPage
About two thirds of the world's cattle, almost all buffalo (97 per cent) and half of all sheep and goats are found in the tropical zones of Africa, Asia and America, regions which support 70 per cent of the world human population. Three quarters of the 3.9 billion people in the tropics live in Asia (Table 2.1).

Table 2.1. Livestock, milk and people in tropical Africa, Asia and Central and South America (Ser et al 1996).

<table>
<thead>
<tr>
<th></th>
<th>Africa</th>
<th>Asia</th>
<th>America</th>
<th>Total (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle and buffalo, (10^6)</td>
<td>165</td>
<td>509</td>
<td>329</td>
<td>1003</td>
</tr>
<tr>
<td>Animal Units (400 kg LW) (10^6)</td>
<td>92</td>
<td>240</td>
<td>262</td>
<td>594</td>
</tr>
<tr>
<td>Milk, m tons</td>
<td>13.2</td>
<td>91.9</td>
<td>44.2</td>
<td>149.3</td>
</tr>
<tr>
<td>Milk, kg/Animal Units</td>
<td>143</td>
<td>382</td>
<td>168</td>
<td>(251)</td>
</tr>
<tr>
<td>People, (10^6)</td>
<td>519</td>
<td>2886</td>
<td>457</td>
<td>3862</td>
</tr>
<tr>
<td>Milk, kg/caput per yr</td>
<td>25</td>
<td>32</td>
<td>97</td>
<td>(39)</td>
</tr>
</tbody>
</table>

Livestock production in the three continents differs in many respects, mainly due to human population density. Compared to tropical Asia, sub-Saharan Africa (SSA) and Central and South America (CSA) have relatively low population densities. Agricultural land (grazing and cropland) is 1.6 ha per person, while in Asia it is 0.3 ha (Table 2.2). Livestock wealth shows a different trend, ranging from 0.08 animal units (AU of 400 kg LW) per person in Asia to 0.18 and 0.57 in SSA and CSA, respectively. Conversely, agricultural land available per AU in SSA is 2.5 to 3.5 times higher than in Asia and CSA, mainly because in the latter the quantities of feed per ha from rain-fed and irrigated cropland (in Asia) and sown pastures (in CSA) are much higher than from the natural range-lands in SSA (Winrock 1992), which provide over 80 per cent of the total livestock feed in Africa (Table 2.2).

These land endowments impact on milk production. In 1993-94, the tropics produced 150 million tons of milk or 36 per cent of the global output (Ser et al 1996). In Africa, three quarters of the milk is produced by cattle, the remainder coming from camels - mainly in the arid zone - and goats (Walshe et al 1991). In Asia, cattle account for 47 per cent of all milk, with most of the remainder produced by buffalo. In CSA, cattle produce almost all milk.

Table 2.2. Land, livestock and people in tropical Africa, Asia and Central and South America (Ser et al 1996).

<table>
<thead>
<tr>
<th></th>
<th>Africa</th>
<th>Asia</th>
<th>America</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing, m ha</td>
<td>745</td>
<td>561</td>
<td>587</td>
<td>1843</td>
</tr>
<tr>
<td>Crops, m ha</td>
<td>127</td>
<td>358</td>
<td>131</td>
<td>616</td>
</tr>
<tr>
<td>Ha/AU</td>
<td>9.5</td>
<td>3.8</td>
<td>2.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Ha/person</td>
<td>1.68</td>
<td>0.32</td>
<td>1.57</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The interplay between people, livestock and land (Tables 2.1, 2.2) has resulted in variable availability of milk. In Africa and Asia, there is about 30 kg per person, one third as much as in CSA (Table 2.1). Milk yields averaged about 60 kg per 100 kg of livestock mass maintained, ranging from 36 kg in SSA to 95 kg in Asia (Table 2.1). The latter is one tenth of the efficiency in the OECD countries (950 kg/AU), where the average dairy cow produces 5100 kg milk per year, compared to 340,900 and 1100 kg per cow milked.
in SSA, Asia and CSA, respectively.

**Sub-Saharan Africa**

As shown in Table 2.1, milk output per AU and per person in SSA is lower than in Asia and America, despite a stocking rate of only 0.1 AU/ha of agricultural land. Milk output is lowest in the subhumid/humid zone because livestock wealth per person is low, fewer cows and goats are milked and off-take per cow is lower than in the other zones (Table 2.3). The highlands of SSA are the most productive in terms of milk per ha, but production per head of cattle is lower than in the dry zone (70 vs 58 kg); this is because the majority of cattle are found in the Ethiopian highlands, where male stock used for traction comprise a high fraction of the herd. However, in the densely populated highlands of Kenya, and to a lesser extent in Tanzania, milk production has risen rapidly due to the widespread adoption of intensive dairy production with crossbred or high-grade cows.

**Table 2.3.** *Livestock, land and milk production in arid/semi-arid, subhumid/humid and highland sub-Saharan Africa (Ser et al 1996).*

<table>
<thead>
<tr>
<th></th>
<th>Arid/semi-arid</th>
<th>Subhumid/humid</th>
<th>Highland</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU/person</td>
<td>0.26</td>
<td>0.10</td>
<td>25.1</td>
</tr>
<tr>
<td>Grazing, ha/AU</td>
<td>10.1</td>
<td>7.4</td>
<td>4.6</td>
</tr>
<tr>
<td>Crops, ha/AU</td>
<td>1.1</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Milk, kg/AU</td>
<td>191</td>
<td>76</td>
<td>135</td>
</tr>
<tr>
<td>Kg/person</td>
<td>49</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Kg/ha</td>
<td>17</td>
<td>10</td>
<td>25</td>
</tr>
</tbody>
</table>

AU = Animal Unit

These zonal differences in production systems reflect, at least in part, dietary and cattle keeping habits of the local population. Whereas in the dry zones and the highlands, cattle keeping and milk consumption has been a long tradition, in the more humid zones cattle keeping has been constrained by tick-borne diseases and trypanosomosis, resulting in a predominance of sheep and goats and minimal dairy production.

**Asia**

The three major agricultural systems in tropical Asia; pasture-based, rain-fed and irrigated crop-livestock, support three quarters of the human population in the tropics or just over half the global human population of 5.5 billion (Table 2.1). The extensive agro-pastoral system is well-endowed with grazing land, covering 70 per cent of the total. Milk production is low (Table 2.4), because livestock are primarily kept for meat, with its beef production accounting for 15 per cent of Asia's total.

**Table 2.4.** *Livestock and milk production in three major agricultural systems in tropical Asia (Ser et al 1996).*
The proportion of irrigated land distinguishes the other two production systems. In tropical Asia, in sharp contrast to sub-Saharan Africa, about a quarter of the cropland is irrigated, with approximately 20 per cent in the `rain-fed' group and 50 per cent in the `irrigated' systems. The two systems are distributed similarly across ecozones: 50 per cent in the semi-arid, 35 per cent in the humid zone and 15 per cent in the highlands. The systems support 2.6 billion people, two-thirds of whom are associated with the high-irrigation system (Table 2.4). Livestock and land capital is greater in the rain-fed system, resulting in higher milk availability per person, and higher milk yields of cattle and buffalo per AU.

In Asia, as elsewhere, the development of dairy production systems is strongly driven by cultural preferences and their market forces. As a result, India and Pakistan, at 75 kg milk per person per year, contribute 96 per cent of all the milk produced in tropical Asia. By contrast, in South East Asia, where 550 million people consume on average 12 kg per person per year, in 1995, two thirds was imported; milk production from local cattle and buffalo is low and dairy systems, as yet, are relatively unimportant.

Central and South America

In Central and South America (CSA) livestock systems can be grouped by eco-zone for the semi-arid and the highland regions, and by production system (pasture-based or crop-livestock) in the humid zone; the latter are the most important as they include 70 per cent of all cattle and two thirds of the land (Table 2.5). Yet, because of the relatively low population density, they include only half of CSA's 456 million people (Table 2.1). The contrast between the two humid zone systems is evident, with livestock wealth and milk production much higher in crop-livestock systems (Table 2.5).

Table 2.5. Land, cattle, milk and people in Central and South America (Ser et al 1996).

<table>
<thead>
<tr>
<th></th>
<th>Semi-arid</th>
<th>Pasture</th>
<th>Crop-livestock</th>
<th>Highlands</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU/ person</td>
<td>0.37</td>
<td>1.54</td>
<td>0.50</td>
<td>0.28</td>
<td>0.57</td>
</tr>
<tr>
<td>Cattle/ person</td>
<td>0.45</td>
<td>1.95</td>
<td>0.65</td>
<td>0.35</td>
<td>0.72</td>
</tr>
<tr>
<td>Grazing ha/AU</td>
<td>2.7</td>
<td>2.6</td>
<td>1.1</td>
<td>2.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap2.html#TopOfPage
Output ratios as a proportion of total milk and meat are 20:42 per cent for the pasture-based and 25:22 per cent for the crop-livestock systems, where productivity per unit of land is four times as high. Livestock in the highlands (mainly the Andean chain of mountains) are found in pasture-based production systems at high altitudes (greater than 2700 m a.s.l.) merging into crop-livestock systems at lower altitudes and in valleys. These systems are diversifying into cash crops (Quiroz et al 1997), explaining the high arable/grazing land ratio.

In the semi-arid zone, mainly concentrated in north east Brazil, arable land in the pasture-based and crop-livestock systems comprises only three per cent of the total land, a quarter of which is irrigated. In terms of livestock output, this region is the least important, as it supports 15 per cent of all cattle and produces only 17 per cent of total milk of the region.

### Dairy production systems in sub-Saharan Africa

Milk production in sub-Saharan Africa amounted to 1.27 million tonnes in 1988, of which three-quarters was produced in East Africa. Cow milk accounted for 80 per cent overall; varying from only half of the milk produced in East and West African to nearly 100 per cent in Central and Southern Africa. Output per TLU (250 kg LW) averaged 70 kg per year, being more than twice as high in East Africa as in the other regions due to the high yield (78 kg /ha) of local cattle in the Sudan and the contribution of intensive dairy production systems in Kenya (Staal et al 1997b).

Self-sufficiency levels varied (Table 2.6); in West Africa, levels in Sahelian countries were high (60-70 per cent) and low in coastal countries with large cities along the seaboard (8-50 per cent). In contrast, all countries in East Africa were relying on local sources (greater than 90 per cent), whereas in Central and Southern Africa, imports ranged from 75 per cent in Rwanda and Burundi to less than 10 per cent in Zaire and Zimbabwe.

<table>
<thead>
<tr>
<th>Region</th>
<th>West (kg)</th>
<th>Central</th>
<th>East (kg)</th>
<th>Southern</th>
<th>Total (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% domestic</td>
<td>61</td>
<td>52</td>
<td>96</td>
<td>68</td>
<td>84</td>
</tr>
</tbody>
</table>

There are three major land-based systems producing milk in SSA, pastoralists, agro-pastoralists and crop-livestock farmers (Walshe et al 1991), representing a descending scale of cattle wealth and therefore potential milk off-take. Household demand and market access determines actual off-take, which ranges from near zero to 500 kg per lactation (de Leeuw and Thorpe 1996). Thus market participation and cattle density are the main determinants of supply, which varies from 2500 to only 80 kg /km², the latter in areas where farmers rarely milk their cows and/or cattle density is low. However, supplies rise to 64 tons.
milk per km² in the densely populated highlands of Kenya, where farmers keep high-grade dairy cattle producing 820 kg head per year (Table 2.7).

An example of the pastoralist system is that practised by the Maasai in the sparsely populated semi-arid range-lands of Kenya (Table 2.7). The Maasai live in extended families (10 to 15 people) with herds averaging 100 to 170 cattle and as many sheep and goats (Solomon Bekure et al 1991). They produce and consume about 0.85 kg of milk per person per day, while the sale of livestock is the main source of income. As few grow crops, most foodstuffs are purchased. Milk surplus is shared with neighbours or exchanged in barter, but is rarely sold, except by households living close (less than five km) to main roads and urban centres where there is demand for fresh and fermented milk, and butter. Similar pastoral systems are found in Southern Ethiopia; working among the Borana. Holden and Coppock (1992) reported that frequency and amounts of dairy products traded depended on herd size and distance to the market: butter replacing liquid milk with increasing distance and women from households with large herds trading more often. Butter was sold to lorry drivers and bus passengers en route to Addis Ababa, some 500 km away.

A contrasting pastoral system is practised in Gambia by Peuhl herders, pastoralists who act as managers of communal herds, the cattle of which are entrusted to them by local farmers who each own a few head (Table 2.7). As sale of milk is the major part of the herder's income, cows and calves are well managed and milk off-take per cow is greater than 400 kg per lactation, or 40 per cent above the yields in family herds of agro-pastoral Peuhl living in a similar environment (Itty et al 1993).

Increasing numbers of agro-pastoralists are found in sub-humid West Africa, where, for example, in Nigeria, small groups of Fulani live among indigenous smallholder farmers, who keep small ruminants rather than cattle. Most Fulani crop small fields of grain (one to two ha), earning their living mostly from sales of milk and live animals, although in Côte d'Ivoire some have become settled farmers growing cotton as a cash crop (Itty et al 1994). Being the main supplier of milk in rural and often to urban areas, diverse trading patterns have evolved. In well-populated areas in Nigeria, for instance (Table 2.7), Fulani women head-load three to five kg of milk to nearby villages, home delivering milk to their regular customers, and selling any remainder on the local market at distances of 2-10 km (Waters-Bayer 1988). Depending on transport infrastructure, women may trade larger quantities, usually bulking up from neighbours and friends.

Table 2.7. Selected examples of the three major land-based systems producing milk in sub-Saharan Africa.

<table>
<thead>
<tr>
<th></th>
<th>(Agro-) pastoralists</th>
<th>Crop-livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kenya</td>
<td>Gambia</td>
</tr>
<tr>
<td>Cattle density, head/ km²</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Milk, kg/ head of cattle</td>
<td>44</td>
<td>85</td>
</tr>
<tr>
<td>Milk, t/ km²</td>
<td>1.54</td>
<td>2.55</td>
</tr>
<tr>
<td>Rural people/ km²</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Milk, kg person/ yr</td>
<td>308</td>
<td>32</td>
</tr>
</tbody>
</table>

Although milk is an important subsistence output of many smallholder crop-livestock systems, it is rarely

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traded, hence the milk supply per person and per km$^2$ are much lower (Table 2.7). Typical of these systems, termed mixed-farming by Walshe et al (1991), are the communal farming areas of Zimbabwe (Steinfeld 1986) and similar systems in West Africa for example in Guinea Bissau (Picaos-Goncalves 1995), where farms and herds are small (1-5 ha, 5-10 cattle), and cattle are used for traction, subsistence milk and manure (Table 2.7).

In the peri-urban areas around larger cities, production and marketing systems are more complex. For example, milk to Bamako, the capital city of Mali, is supplied by two types of producers: high-input large scale dairies using crossbred cattle close to the town, and peri-urban (within 25-40 km) communal dairies producing milk from herds of local cattle assembled from several owners (Achonjie and Debrah 1992). Many of the large-scale owners (herds of up to 200) delivered milk directly to the co-operative processing plant to be added to imported reconstituted milk. Others, selling directly to consumers, accounted for half of the informally marketed milk; the rest was delivered to consumers through one to three intermediaries. Similar peri- and intra-urban production systems operate in Addis Ababa, Ethiopia (Staal 1995), where over 70 per cent of milk was sold directly to consumers mainly from small landless dairy enterprises located within the city (Debrah 1992). The remainder was sold through itinerant traders, small shops, kiosks and larger grocery stores.

When smallholder crop-livestock systems are supported by market infrastructure, dairy can become a major component, especially as systems intensify in the face of increasing human population pressure. In the densely populated Kenya highlands (Table 2.7), after independence milk production shifted from large-scale, herds to smallholder crop-livestock farms, which also grew coffee and tea, and vegetables and fruit closer to the urban centres (Tiffen et al 1994). Hence, the milk enterprise became integrated into multipurpose farming systems, relying on cash crops, maize and beans, supported by off-farm income from towns through the extended family network. Farms are frequently one to two ha in size with one to two cows (generally Holstein Friesian or Ayrshire) comprising 50 per cent of the herd, the other half consisting mainly of female calves and heifers. Feeding is mainly cut-and-carry with planted Napier grass (Pennisetum purpureum) and crop residues, especially from maize and bananas (Staal et al 1997a). On average total daily milk output is 10 kg per farm, of which a quarter is for home consumption and the rest sold. In the late 1980s, sales were mainly through local dairy co-operative societies, with some to neighbours, but since economic reforms and liberalisation of trade, marketing channels have diversified, with a larger proportion of direct sales to private and institutional consumers (Staal et al 1997b).

Characteristic of tropical regions with good market access, the development of smallholder dairy systems in the Kenya highlands is marked by three elements: declining farm size, upgrading into dairy breeds and an increasing reliance on purchased feeds, both concentrates and forage, resulting in milk yields per lactation increasing by as much as five times, while milk yield per ha of land planted with forage rose by a factor of 40 (de Jong 1996).

The range of systems found in sub-Saharan Africa is captured at a country level in Tanzania, which has some 15.5 million cattle distributed across three major systems producing milk (Table 2.8). It is estimated that there are 110,000 agro- pastoral households, who own and manage 7.8 million cattle, many of which are in large herds similar to those of the Maasai in Kenya (Table 2.7). Potential milk production is probably 55 kg milk per head per year, but since milk is mainly used for subsistence, only half (28 kg) is actually extracted for human consumption, because households with large herds only exploit 20 per cent of the yield potential (Grandin 1993). In areas of higher rainfall, over three million crop-livestock farmers with smaller herds (five to eight head) form the largest production system, producing some 45 per cent of milk nationally. They realise yields of 45 kg /ha /yr, which is closer to potential.

**Table 2.8. People, cattle and milk in Tanzania (Omore and Staal 1998).**
In the third system, in 1997 246,000 crossbred and high-grade cows in 60,000 holdings produced 0.19 million tons of milk (Omore and Staal 1998). Over 70 per cent of these dairy cattle are found in the small-scale intensive production system in the highlands and in peri-urban herds, the majority being stall-fed crop by-products and planted forage or harvested natural pasture. The remainder practice grazing of natural pastures, often supplemented with crop residues, some fodder and/or concentrate. There is significant intra-urban dairy production from small herds, often owned by civil servants, based on purchased forage or grazing public land. Larger herds, some grazing paddocks, are found in the peri-urban areas.

In spite of their relatively small numbers, these dairy cattle contributed some 90 per cent of all marketed milk. In 1997, about 90 per cent of the marketed milk was delivered informally, either by direct sales to customers (60 per cent) or through vendors (30 per cent); the remainder was marketed by co-operatives and retailers (Omore and Staal 1998). The very small contribution of the extensive and semi-intensive production to milk markets (10 per cent of market flow from 98 per cent of the animals) is indicative of the separation of these systems from the major urban consumption centres, and the inadequate market infrastructure to link them. This is further indicated by large price differentials between rural and urban areas, indicating relative deficit and surplus areas.

These production systems in Tanzania illustrate the principles common to dairy production in SSA: the potential to increase milk production from pastoralist and agro-pastoralist systems depends on the cost of collection and transport, particularly where distance-sensitive informal (raw milk) markets predominate. In turn, unit costs of the support services such as input supply; animal health services; milk marketing, decrease as production increases (Walshe et al 1991). Consequently, production systems nationally can become highly differentiated in structure of production and achievement of biological potential.

### Dairy production systems in Asia

In tropical Asia, dairy production is concentrated in the rain-fed and irrigated crop-livestock systems of India, which account for most dairy cows and buffalo and over 90 per cent of all Asian milk production (Table 2.4). Milk production in India increased from 17 million tons in 1951 to 54 million tons in 1991 and is expected to rise to 86 million tons in 2000. The urban sector (28 per cent of the population) consumed 56 per cent, three times as much per person as the rural population (Table 2.9). Per person availability has increased to 72 kg per year, in part the result of 40 years of intensive dairy co-operative development under Operation Flood (Patel 1997), as well as the still-larger private and informal markets. Religious beliefs forbidding slaughter and beef consumption at least in part explains the exceptional emphasis on milk production.

#### Table 2.9. People and milk consumption in India in 1995 (Aneja and Puri 1997).
People (million) | Milk (million tons) | Consumption (kg/person/year) |
---|---|---|
Rural | 660 | 29.2 | 47 |
Urban | 254 | 37.1 | 148 |
Total/mean | 914 | 66.3 | 72 |

India is also exceptional in that - despite this vast expansion of milk output - dairying is characterised by a predominance of small-scale producers farming little or no land and a reliance on indigenous breeds of cattle and buffalo; in 1996-97, crossbred dairy cattle were only eight per cent of the total; buffalo produced 55 per cent of all milk.

The contribution of buffalo to dairy production in part reflects a shift from their importance as traction animals in smallholder farming systems (Table 2.10). Herd structures and their changes between 1966 and 1987 reflect the increasing emphasis on dairy production. The percentage of females greater than three years of age remained constant, but the proportion of cows in milk increased: from 45 to 49 per cent for cattle and 50 per cent to 60 per cent for buffalo.

Table 2.10. Composition of cattle and buffalo herds in India in 1966 and 1987 (Kurup 1997).

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th>Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1966</td>
<td>1987</td>
</tr>
<tr>
<td>Cows &gt; 3 yr, %</td>
<td>29.4</td>
<td>30.5</td>
</tr>
<tr>
<td>In milk, %</td>
<td>11.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Dry, %</td>
<td>17.5</td>
<td>15.6</td>
</tr>
<tr>
<td>Males &gt; 3 yr, %</td>
<td>43.2</td>
<td>37.4</td>
</tr>
<tr>
<td>Working, %</td>
<td>40.0</td>
<td>36.6</td>
</tr>
<tr>
<td>Others, %</td>
<td>3.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Young stock, %</td>
<td>27.3</td>
<td>31.5</td>
</tr>
<tr>
<td>Total, %</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

In 1991 59 per cent of the farms were less than one ha, 44 per cent (46 m) of which were classified as landless (Table 2.11). Together, these holdings comprised 15 per cent of land under cultivation (Aneja and Puri 1997). Out of India's 105 m farms, 60 m (67 per cent) were milk producers who, on average, produced 2.5 kg per day. Whereas land is unequally distributed, dairy stock holdings are not, and neither are there large differences between milk yield per animal across the three groups of farmers (Table 2.11).

Table 2.11. Distribution of dairy animals and milk production amongst landless, small/marginal and medium/large scale producers in India (de Jong 1996).

<table>
<thead>
<tr>
<th>Type of farmer</th>
<th>% of farmers</th>
<th>% of dairy animals</th>
<th>% of milk production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td>26</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Small and marginal</td>
<td>49</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

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In contrast to the grass-based dairy production systems in most of the tropics, in India milk is produced mainly from crop residues. Singh et al. (1997) show that two thirds of the available feed originated from cropped land, 25 percent of which is irrigated and often double cropped. Four percent of the cropped land is grown to forage crops providing another 12 per cent of the total feed, while grazing supplies only 14 per cent of all feed. The organised animal feed industry sector is small, but developing rapidly, producing 1.5 million tons of cattle feed and 1.2 million tons of poultry feed in 1995.

Unlike in India, the dairy production systems in Sri Lanka and in other parts of Asia mirror those seen in sub-Saharan Africa (section 3), ranging from indigenous cattle communally grazing relatively dry lowlands to intensive zero-grazing enterprises with cross-bred cows producing 1500 kg of milk per year (Table 2.12) and up to 11 tons of milk per ha of farmland.

Herd and farm size in Sri Lanka decline with altitude, but stocking rates per farm increase, implying an increasing use of off-farm feed sources, such as coconut plantations and forest gardens (Table 2.12). In the midlands and uplands, smallholder crop-livestock farmers are the major milk producers, many of whom added dairy to their farming enterprise mix in the late 1970s, acquiring crossbred dairy cattle on credit (de Jong 1996). Herds are small (mostly two to three head) but represent 3.5 TLU per ha of farmland, with cows comprising half of the total stock. Peak milk yields averaged 6.6 kg per day (2700 kg per ha), 4.1 kg per day of which were sold. Most of the farm land was occupied by tree crops (tea, coconuts, bananas, fruits) and vegetables, which provided 30 per cent of the on-farm net income (but only 14 per cent of total net income), milk and animals sales accounting for 57 per cent and 13 per cent, respectively.

### Table 2.12. Characteristics of cattle production in smallholder farms in Sri Lanka (adapted from de Jong 1996).

<table>
<thead>
<tr>
<th>Eco-zone¹</th>
<th>Feed source</th>
<th>Milk (kg/ha)</th>
<th>Beef (kg/ha)</th>
<th>Milk (kg/cow/yr)</th>
<th>Farm size (ha)</th>
<th>Farm size (cows)</th>
<th>Milk/farm (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-L</td>
<td>Communal land</td>
<td>1580</td>
<td>220</td>
<td>170</td>
<td>1.3</td>
<td>12.1</td>
<td>6.7</td>
</tr>
<tr>
<td>D-I</td>
<td></td>
<td>1840</td>
<td>105</td>
<td>270</td>
<td>1.5</td>
<td>10.2</td>
<td>4.7</td>
</tr>
<tr>
<td>I-L</td>
<td>Coconut</td>
<td>850</td>
<td>45</td>
<td>300</td>
<td>1.2</td>
<td>3.5</td>
<td>2.9</td>
</tr>
<tr>
<td>W-L</td>
<td>Plantations</td>
<td>3270</td>
<td>60</td>
<td>620</td>
<td>0.7</td>
<td>3.7</td>
<td>6.3</td>
</tr>
<tr>
<td>I-M</td>
<td>Forest Gardens</td>
<td>2080</td>
<td>35</td>
<td>940</td>
<td>0.8</td>
<td>1.7</td>
<td>5.3</td>
</tr>
<tr>
<td>I-U</td>
<td></td>
<td>2040</td>
<td>35</td>
<td>1070</td>
<td>0.8</td>
<td>1.6</td>
<td>4.7</td>
</tr>
<tr>
<td>W-U</td>
<td></td>
<td>3130</td>
<td>50</td>
<td>1550</td>
<td>0.7</td>
<td>1.5</td>
<td>6.4</td>
</tr>
<tr>
<td>D-L</td>
<td></td>
<td>10970</td>
<td>310</td>
<td>1490</td>
<td>0.5</td>
<td>3.6</td>
<td>14.7</td>
</tr>
</tbody>
</table>

¹. Rainfall: Dry (D): < 2000 mm; Intermediate (I): 2000-2500 mm; Wet (W): >2500 mm.
Altitude: Lowland (L): <500 m; Mid-altitude (M): 500-1000 m; Upland (U): > 1000 m.
Dairy production is an integral part of smallholder agriculture and landless livestock systems in south Asia whereas, in SE Asia, it is relatively unimportant, but is developing quickly in response to market demand. In Thailand, as with most SE Asian countries, milk was not part of the traditional diet prior to 1970. In 1954, the country was one of the poorest in the world, but between 1970 and 1990, the GNP per person quadrupled, and is expected to rise by another 50 per cent by the year 2000.

Thailand has 7.2 million cattle and 4.7 million buffalo, and the livestock share of the agricultural GNP is about 12 per cent, with the pig and poultry industry being the most important (Danida 1994). Ready-to-drink milk consumption took off in the mid-1970s reaching 40,000 tons in 1984, and 350,000 tons in 1993. Local fresh milk deliveries followed the same trend, increasing seven-fold between 1980 and 1993, supplying 19 per cent of total consumption. Fresh milk was produced by about 150 dairy farmers in 1971, increasing in 1993 to 12,500 with a total of 48,000 cows, supplying 133,000 tons of milk (equivalent to 10.6 t per dairy farmer).

The characteristics of this rapidly expanding dairy production are summarised in Table 2.13 for three locations with increasing farm size. Herds were relatively large, generally Friesian-Holsteins and their crosses grazing fenced pastures, producing 2000 kg milk per cow per year. Concentrate feeding averaged five to six kg per day for cows in milk and two kg for dry cows. Feed costs were about 70 per cent of total operating costs, the largest being expenditure on concentrates (65-80 per cent). Over 30 per cent of the sampled farmers sold more than 100 kg of milk per day and several had invested in milking machinery. Milk collection was privatised and fees amounted to 7-10 per cent of the operating cost. In 1993, production from this high-input system was barely profitable, and it was recommended that dairy production be better integrated with crop production, taking advantage of the benefits of whole farm productivity enjoyed by smallholder dairy producers in South Asia and East Africa.

Table 2.13. Characteristics of dairy farms in Thailand by farm size (adapted from Danida 1994).

<table>
<thead>
<tr>
<th></th>
<th>Farm size</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
<td>Average</td>
</tr>
<tr>
<td>Farm size, ha</td>
<td>1.3</td>
<td>8.1</td>
<td>12.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Total herd, head</td>
<td>29.0</td>
<td>20.6</td>
<td>22.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Total cows</td>
<td>15.4</td>
<td>13.3</td>
<td>9.0</td>
<td>14.3</td>
</tr>
<tr>
<td>Cows in milk, %</td>
<td>74</td>
<td>58</td>
<td>64</td>
<td>71</td>
</tr>
<tr>
<td>Milk, kg/cow/yr</td>
<td>2254</td>
<td>1845</td>
<td>2303</td>
<td>2365</td>
</tr>
<tr>
<td>Milk sales, kg/d</td>
<td>95</td>
<td>67</td>
<td>88</td>
<td>92</td>
</tr>
<tr>
<td>Milk, t/ha/yr</td>
<td>27.4</td>
<td>3.1</td>
<td>2.8</td>
<td>6.9</td>
</tr>
</tbody>
</table>

In summary therefore, dairy production in Asia is dominated by the crop-based systems of India, where buffalo milk is increasingly important. The development of efficient dairy production in India, with substantial welfare benefits for millions of poor households, has resulted largely from the effective output/input market services provided by village-level co-operatives. Private sector (some informal) milk markets remain as important, however. As the demand for milk and dairy products increases in Asia, driven by urban consumers, especially in SE Asia, the lessons from India and Sri Lanka can play an important role in guiding the development of smallholder dairy systems in the region.
Dairy production systems in Latin America

Tropical America, despite its large ecological diversity, can be divided into two broad zones: the lowlands (less than 1000 m asl) and the highlands (greater than 1000 m). The Andean mountain range divides the lowlands bordering the Atlantic Ocean in the east and those bordering the Pacific Ocean in the west. Two major dairy production systems have evolved: dual-purpose cattle enterprises in the lowlands, mainly of large and medium scale, and the smaller scale crop-livestock systems in the highlands. Generally, land is privately owned, feeds are derived mainly from sown pastures, and a large proportion of the milk and dairy products are marketed.

The evolution of the production systems in the lowlands has involved intensification from pure beef to dual-purpose beef-milk and eventually to milk-beef (Berry 1985; Wadsworth 1992). Changes were most prominent in the tropical lowlands where large-scale enterprises predominate. The gradual shift followed progressive steps, the outcomes of which are quantified in terms of land use and beef and milk output per ha in Table 2.14.

**Table 2.14. Variables of beef, dual-purpose (DP) and dairy systems in Costa Rica and Mexico.**

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>DP1</th>
<th>DP2</th>
<th>Dairy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size, ha</td>
<td>74</td>
<td>43</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>LSU/ha</td>
<td>0.95</td>
<td>1.62</td>
<td>1.21</td>
<td>2.01</td>
</tr>
<tr>
<td>Milk, kg/cow/yr</td>
<td>220</td>
<td>560</td>
<td>1715</td>
<td>3490</td>
</tr>
<tr>
<td>Milk, t/ha/yr</td>
<td>0.10</td>
<td>0.46</td>
<td>1.26</td>
<td>3.48</td>
</tr>
<tr>
<td>Beef, kg</td>
<td>70</td>
<td>133</td>
<td>142</td>
<td>124</td>
</tr>
<tr>
<td>LW/ha/yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk income3, %</td>
<td>32</td>
<td>53</td>
<td>75</td>
<td>95</td>
</tr>
</tbody>
</table>

1. Data for Costa Rica (Wadsworth 1992); LSU = one cow.

**Intensification of cattle production systems in LAC**

**From beef to milk production**

1. from indigenous stock (Zebu, Criollo) to upgrading with dairy breeds
2. reducing calf weaning age
3. from opportunistic short term milking to exploiting the entire lactation.
4. from use of milk for household needs and limited cheese production to maximising daily sales of liquid milk
5. increased proportion of cows; sales restricted to weaned calves and culled cows
6. simultaneous specialisation of beef enterprises into outgrowing and fattening.
Intensification of feeding systems

1. shift from natural pasture to sown grasses and grass/legume mixtures, leading to higher stocking rates
2. increased fertiliser use, rotational grazing and allocation of the best pastures to lactating cows
3. increased supplementary feeding of concentrates and agricultural by-products.

Dual-purpose systems

In the large-scale dual-purpose systems, crossbred (mostly Friesian Holstein (HF) or Brown Swiss x zebu) cows are milked by hand and managed in pasture-based systems. Generally male calves are sold when weaned. Holmann et al (1990) documented examples of these systems in the humid (rainfall 2900 mm) and dry lowlands (rainfall 1300 mm) of Venezuela:

1. farm size 285-950 ha; cows: 180-380 head
2. stocking rates, cows per ha: humid 0.70; dry 0.50
3. age of first calving: 30 months; calving rate: 0.73
4. milk yield: > 50 per cent HF, 3500 kg per cow per yr; 2.1 t/ha
5. < 50 per cent HF, 2650 kg per cow per yr; 1.6 t/ha
6. income from milk about 75 per cent of total
7. concentrate feeding as kg milk/kg feed: humid 15; dry 5.5.

In terms of intensity of milk production, the ranches in Venezuela resemble the dual-purpose system in the SE of Mexico (Table 2.14), but in Venezuela, calving rates and milk yields were higher, the scale of operation much larger and stocking rates lower. Although the proportion of income from milk sales was similar, the outgrowing of male stock was less common in Mexico. These dual-purpose systems benefit from the ability to shift the emphasis of production between beef and milk, a flexibility reflected in incomes from milk ranging from 25 per cent to 75 per cent of the total (Wadsworth 1992). Specialised beef production systems can be found side by side with dual-purpose systems, as observed in the SE of Mexico where beef systems were in the majority (Anderson et al 1992).

Intensive milk production

Intensive (or specialised) dairy systems of all scales occur in tropical America; the medium-scale dairy farms presented in Table 2.14 practice high stocking rates and achieve high milk yields per cow and per ha. Large-scale specialised dairy enterprises in the Venezuelan highlands manage pure Holstein cows yielding annually 5800 kg milk, with income from milk sales reaching 93 per cent. Feed comprised 77 per cent of total costs, two thirds of that being for purchased feed. Output of milk per ha was 12.2 t, higher than equivalent systems in Costa Rica (Table 2.14), in part due to the effects of the contrasting highland and lowland environments on the performance of pure Holstein cows (Holmann et al 1990).

In Costa Rica, intensive small-scale dairy farms in the lowland zone with high rainfall rely on planted pastures (Brachiaria, Cynodon) and high stocking rates (Table 2.15). Holmann et al (1995) reported that between their establishment in 1979-80 up to 1990, performance declined due to invasion of unpalatable
low yielding grasses, exacerbated by low fertiliser inputs (Table 2.15). Combined with low levels of concentrate feeding, this led to a decline in milk yields and net incomes. Attempts to expand farm sizes and diversify back into beef production did not stem the loss of income, illustrating the importance of skilled management for efficient and profitable dairy production, especially in intensive systems.

In common with East Africa and South Asia, small-scale intensive crop-dairy systems have developed in the sub-tropical highlands (1200-2700 m) of Central and South America where rainfall varies between 1600 to 2800 mm and falls seven to 12 months of the year. Many of the soils are volcanic and fertile, and coffee is a major cash crop (Quiroz et al 1997). As human population densities are, as yet, lower than in parts of East Africa, the systems are still largely pasture-based, often in rotation with vegetables and potatoes, while diversification into fruits and flowers for exports has been developing rapidly in recent years. Intensification has led to combining grazing and stall-feeding of planted forage (for example, Napier and King grass) supplemented with molasses, other sugar crop by-products, green bananas, plantain pseudo-stems and brewer's grains. These locally available by-products are gradually replacing more expensive commercial feeds. Pure Holstein-Friesian cattle predominate, producing an average of 16 kg of milk per day (range: 5-27 kg) and fed concentrates at rates of one to 10 kg per day. Liquid milk and cheese are the main marketed products: cheese making has increased particularly in more distant regions of the highlands of Ecuador and Colombia (de Jong 1996).

Table 2.15. Changes in the performance of smallholder dairy farms at two sites in the lowlands of Costa Rica, 1980-90 (Holmann et al 1995).

<table>
<thead>
<tr>
<th></th>
<th>Rio Frio</th>
<th>Somafluca</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farm size, ha</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.6</td>
<td>17.6</td>
</tr>
<tr>
<td><strong>Per cent pasture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td><strong>Stocking rate (AU/ha)</strong></td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Total herd (AU)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18.3</td>
<td>31.3</td>
</tr>
<tr>
<td><strong>Cows, head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.6</td>
<td>21.6</td>
</tr>
<tr>
<td><strong>Pasture degradation</strong></td>
<td>(%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>94</td>
</tr>
<tr>
<td><strong>Fertilisers (N, kg/farm/yr)</strong></td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td><strong>Supplements (kg/cow/d)</strong></td>
<td>2.0</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Milk (kg/cow/d)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>Milk (t/ha/yr)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.43</td>
<td>2.41</td>
</tr>
<tr>
<td><strong>Net income ($/ha/yr)</strong></td>
<td>1044</td>
<td>440</td>
</tr>
</tbody>
</table>

These intensive highland systems, which extend into the Andean eco-region, take advantage of the favourable agro-ecology for milk production (Quiroz et al 1997). As elsewhere in the tropics, these smallholdings demonstrate the high productivity possible in crop-dairy systems, which can exploit the important complementarities between crops and livestock consistent with the risk-aversive strategies of resource-poor households world-wide. The pasture-based dual-purpose systems of Latin America are another strategy by which risks are reduced, and these diversified systems contrast with the specialised, generally large-scale, intensive dairy farms found in the region.
Conclusions

Milk production in the tropics has some continent-specific characteristics: in sub-Saharan Africa, three quarters of the milk is produced by cattle, with common property natural pastures providing most of the feed; by contrast in Asia, where cattle produce half of the milk, and most of the remainder comes from buffalo, crop residues are the major feed source; whereas in Latin America, most milk comes from cows grazing privately owned planted pastures. Over-riding these characteristics of production systems are the effects of the market; throughout the tropics, with the exception of India and parts of Latin America, market-oriented dairy farms are concentrated near or within urban consumption centres. Less proximate production occurs only in those regions where there is an efficient market infrastructure. Therefore, the potential to increase dairy production depends largely on the unit costs of collection and transport. Those in urban peripheries are doubly advantaged, because with better access to markets, the unit costs of the support services such as input supply, animal health services and milk marketing decrease as production increases (Walshe et al 1991).

The advantages of integrating dairy production into crop systems, however, also offer potential. Compared to pastoralists and agro-pastoralists, crop-livestock farmers have more control over feed inputs, and are able to capture complementarities in feed resource use and nutrient cycling, which increase overall farm efficiency and reduce vulnerability to market shifts. As these crop-livestock systems generally support high rural population densities, intensification is characterised by declining farm sizes, the upgrading to cattle and buffalo dairy breeds and an increasing reliance on purchased fodders and concentrates. As a result, lactation yields increase up to five-fold (de Jong 1996).

In these smallholder dairy production systems, especially those close to urban centres, informal raw milk marketing is often the general rule. Such markets are particularly susceptible to distance. As infrastructure develops, markets become more efficient, and urban consumers develop stronger preferences for pasteurised milk, the advantages of proximity will be reduced and production may well move away from intensive peri-urban systems and shift to more extensive systems, as the New Zealand dairy industry illustrates on a global scale. But the advantages of mixed crop-livestock production remain, and until these infra-structural improvements occur, the industrialised model of dairy production and processing is likely to remain a minor contributor to dairying in the tropics.

In the meantime, dairy production will contribute significantly to the sustainable intensification of smallholder agriculture in the tropics, thereby enhancing the welfare of millions of poor households, whether through their participation in milk production, processing or marketing. These benefits of dairy production are especially important to the landless poor, who, during the next 20 years, will increase significantly not only in Asia, but throughout the tropics.

References


Woman carrying fodder to stall-fed *Bos taurus* and crossbred cattle in smallholder intensive dairy cattle production system in Kenya highlands. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Hand spraying of a *Bos taurus* cow with a tick acaricide in smallholder intensive dairy cattle production system in Kenya highlands. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)

Hand milking of a crossbred cow in a semi-intensive dairy cattle production system in Bolivia.
Hand milking of a *Bos indicus* Bunaji (white Fulani) cow in extensive agro-pastoral dairy cattle production system in sub-humid south-western Nigeria. (Photograph by D. Elsworth, ILRI)

Milk weighing and sale at a dairy co-operative society in Kiambu District, Kenya. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Urban dairying with local cattle genotypes in Madhya Pradesh, India. (Photograph by J. Tanner, ILRI)

Ferrying of planted Napier grass (*Pennisetum purpureum*) fodder by donkeys in Kiambu District, Kenya. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Ferrying of natural Kikuyu grass (*Pennisetum clandestinum*) fodder by bicycle for sale in Kiambu District, Kenya. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)

Woman feeding Napier grass (*Pennisetum purpureum*) to her cow in an enclosure next to her house in Kiambu District, Kenya. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Raw milk sale by a smallholder producer to a neighbour in peri-urban Nairobi. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)

Roadside grazing of Ayrshire cows in Kiambu District, Kenya. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Hand milking of a *Bos taurus* cow in smallholder intensive dairy cattle production system in Kenya highlands. (Photograph by Market-oriented Smallholder Dairy Programme, ILRI)
Chapter three
Socio-economic aspects of smallholder dairy farmers
A. J. De Boer

Introduction
Dairy production systems, as well as the processing, distribution and consumption patterns for milk are undergoing tremendous changes and stresses at the present time. This book represents a timely opportunity to examine trends leading to this dynamic situation and to examine ways in which smallholder dairying in developing countries can increase its contribution to the well being of farmers and generate additional employment, value added and consumer demand in an economic fashion. Some factors, which have had an impact on smallholder dairying in the tropics over the past decade, include:

1. rapid growth in urban consumer demand for both traditional and non-traditional dairy products
2. increasing land prices in many dairying regions which affects the cost structure and opportunity costs of staying in agriculture, in general, and dairying in particular
3. increased volatility of feed ingredient prices in world markets as stocks previously held in developed countries decrease
4. trade liberalisation which is gradually breaking down highly protected dairy industries in both developed and less developed countries

5. decreasing export subsidies for a range of dairy products and decreased surplus of dairy products held by developed countries

6. technological changes constantly increasing yield per cow in both developing countries, and developed countries

7. decreasing subsidies for inputs, such as water, fertiliser, seeds, feedstuffs, credit, and fuel

8. increased private sector participation in all aspects of dairying, and

9. rapid migration of labour on both a permanent and seasonal basis from rural to urban areas, leading to regular labour shortages of rural labour.

There is no indication that these trends will change in the near to medium-term although the speed of change may vary considerably. However, the trend towards globalisation of economic activity seems clearly in place and these trends will profoundly affect the dairy industry in developing countries as well as developed countries. The balance of this chapter provides background on the structure and evolution of dairying in the tropics, examines each of the above factors as to their potential impact on smallholder dairy farmers in the tropics and concludes with recommendations needed to retain and promote this industry under a more open, and competitive world economy.

Smallholder dairy farming systems

Smallholder dairying is invariably part of a larger and more complex farming system that typically includes farm-produced inputs such as feeds, various off-farm inputs, family inputs of labour and management and outputs of various types. The latter include the obvious ones such as milk and calves but less obvious ones such as dung, draught power, capital accumulation and risk aversion. Farming systems research (FSR) arose in part from non-adoption of Green Revolution crop technologies. These were often found unsuitable for the socio-economic circumstances faced by smallholders who, while economically rational, were risk-averse and sharply constrained by an uncertain environment, shortages of funds and lack of experience with how the technologies might perform under their circumstances (Simmonds 1986). Therefore, the nature and direction of the research process needed to be reversed so research could arise from specific farmers' needs through a better understanding of their farming systems and circumstances. This is equally applicable to research on animal production technologies and has been applied recently. These include the USAID-financed Small Ruminants Collaborative Research Support Programme, programmes of the International Centres for Agricultural Research [International Centre for Agricultural Research in the Dry Areas, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Livestock Research Institute and the International Rice Research Institute] and the Bioconversion of Crop Residues and Fibrous By-Products for Dairy Animals (BIOCON), a project between the Indian Council of Agricultural Research and Wageningen Agricultural University in the Netherlands.

Types of systems

Dairy production systems in developing countries may be identified by a combination of characteristics (Sohal 1979). These include buffalo or cows; small versus medium versus large units; mixed farming versus specialised dairy units; urban or rural-based production; public versus private sector participation
in production, processing, procurement and distribution; breed improvement versus feed improvement; upgrading existing breeds or developing synthetic breeds; dual purpose or single purpose breeds; and decisions to focus development efforts on high-potential areas for dairying versus a diffusion strategy to reach the maximum number of current or potential producers.

To simplify these systems we can focus on four basic production systems classified according to primary use of animals and consumption of dairy products:

1. Specialised milk production for home consumption, where milk is an essential part of the household diet.
2. Milking dual-purpose animals where seasonal surpluses of milk are converted into market sales of storable household products.
3. New, specialised dairy systems for market sales.
4. Extensive, grazing-based systems for home consumption, often based on small ruminants.

Using these breakdowns, analysts can then look at the strengths and weaknesses of each system and devise improvement or adjustment strategies.

An alternative approach, more oriented towards farm-level management, resources and constraints, places primary emphasis on feed resources available to smallholders. Earlier work by Wilkens et al (1979) classifies production systems by management practices and feed sources at the farm-level. A more detailed breakdown for Asian systems in general was developed during an Asian Development Bank workshop in 1984 (Camoens et al 1985). This is a particularly useful reference for setting out procedures to link inputs, outputs, external forces and policies in a farming system approach to improvement of the animal component.

Economics of dairying in the tropics is difficult to analyse at a single stage of the production-collection-processing-distribution-consumption continuum (De Boer 1981). Often, improvements in one area create opportunities in another, such as a recent study of small-holders in South India, which found that an improved collection system would lower costs and stimulate more production by local dairy farmers(Vijayalakshmi et al 1995).

**Post-milking considerations**

Most of this chapter deals with problems and opportunities faced by the dairy farmer. However, the key to on-farm incentives to make the necessary investments, changes in management and adoption of technological change is developed of an efficient and profitable milk procurement system. Procurement must be linked to milk handling, hygiene, processing, distribution and storage. Thus ensuring the benefits from increased demand and product diversification reach the primary producer (De Boer, 1981). This is the most complex link for smallholder dairy development and requires the greatest organisational skills, innovations and capital investments.

This follows from the features of smallholder dairying: a small marketable surplus per farm, poorly developed procurement and transportation infrastructure, and an often-dispersed market for the final products. This is changing, however, with rapidly increasing urban population centres often serving as the primary market. The problem then becomes how to procure enough raw milk from widely dispersed smallholders to economically meet these demands, in competition with imported products. The latter are not subject to the same complexities of procurement, quality control and seasonality that face the smallholder dairy sector.
Technological change and technology transfer for smallholder dairying

Background

The use of Farming Systems Research / Extension (FSR/E) is often suggested as a tool for promoting technological change and technology transfer for smallholders. It has seldom been applied to animal production in its full scope. A recent research and extension project in India (De Boer and Singh 1995; Schiere et al 1997) attempted to use this tool for dairy development in India.

Until recently, farmers themselves carried out agricultural innovations almost entirely. The current system of organised, publicly supported agricultural research and extension is a fairly recent phenomenon. The gradual development of scientific agriculture shifted the process of generating technology, away from farms, and on to research stations and laboratories. The direct link between farmers' needs, environments and resources, while not broken, was weakened, particularly for smallholders with limited commercial involvement and influence of the agricultural research system. The increased emphasis on FSR was in response to this widening gap and that many innovations associated with the Green Revolution were not being adopted by farmers (Byerlee et al 1982). That is, the innovations proposed were generally not suitable for the socio-economic circumstances of farmers.

There are a number of stages of FSR/E ranging from four to six according to different researchers. For simplicity, we used the following stages for the work in India (Singh et al 1995):

1. diagnostic stage
2. design stage
3. testing stage, and
4. dissemination stage.

However, one more stage is also observed between the third and fourth stages in some projects; ‘Pilot Development Programme’ which is, often found useful for livestock research and development.

Methods

To implement these objectives, some very specific procedures were used. The first step used agro-ecological zoning and transects while the second step used Rapid Rural Appraisal (RRA) methods. These methods were backed up by secondary data and existing surveys, as well as group knowledge gained while discussing information from zoning and transects. The third and fourth steps used roundtable discussions from the research group as well as extension personnel and industry leaders. These comprised the diagnostic and design stages, which led to a series of constraint analysis and carefully formulated on-farm trials. They also led to the testing stage. Some advanced technologies that showed potential widespread application were used in Pilot Development Programmes prior to the development of extension and dissemination campaigns directed specifically at target areas and target groups defined under the Farming System groupings developed in stages I and II. Various methods for screening potential technologies represented a convenient means to synthesise information gathered from these stages and combine this with scientific knowledge about the technologies and their impact on animal performance. We can look at factors influencing technology acceptance or rejection by listing positive and negative factors as well as the best case, a ‘perfect fit’ to the farmer’s conditions. An example developed for urea treated straw in Bangalore state, India illustrates this procedure (Rao et al 1995). This was used to determine specific farming systems that had most or all of the favourable characteristics (the ‘best fit’
situations) and on-farm trials were started in those systems. Conversely, farming systems with few examples of a good fit should not be targeted for introduction of urea treated straw (Table 3.1).

**Table 3.1. Urea treated straw ‘fit’ exercise (Rao et al 1995).**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Importance</th>
<th>‘Perfect fit' case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of straw</td>
<td>Important</td>
<td>Slender straws</td>
</tr>
<tr>
<td>Labour cost/availability</td>
<td>Important</td>
<td>High availability, low cost</td>
</tr>
<tr>
<td>Farm type (landless, small, medium, large, etc.)</td>
<td>Important but more work needed</td>
<td>Large farm probably best</td>
</tr>
<tr>
<td>Availability of straw</td>
<td>Important</td>
<td>Good supplies</td>
</tr>
<tr>
<td>Type of animal</td>
<td>Important</td>
<td>Medium to high productivity</td>
</tr>
<tr>
<td>Water availability</td>
<td>Important</td>
<td>Readily available at household</td>
</tr>
<tr>
<td>Green fodder availability</td>
<td>Important</td>
<td>Limited availability, high cost</td>
</tr>
<tr>
<td>Concentrate availability</td>
<td>Important</td>
<td>Limited availability, high cost</td>
</tr>
<tr>
<td>Cost and availability of urea</td>
<td>Important</td>
<td>Low urea cost, plentiful supplies</td>
</tr>
<tr>
<td>Cost and availability of plastic covering</td>
<td>Important</td>
<td>Low cost and good quality</td>
</tr>
<tr>
<td>Market price of milk</td>
<td>Important</td>
<td>High milk price</td>
</tr>
<tr>
<td>Support services</td>
<td>Important</td>
<td>Good to excellent in first stage of adoption</td>
</tr>
</tbody>
</table>

A more comprehensive process looks at a number of options. In the Indian work with dairy animals, this included urea treated straw, supplementation, chopping/chaffing straw, soaking with a concentrate or urea molasses mineral blocks (UMMBL). Table 3.2 examines the screening or ‘constraints analysis' which followed stages I and II of the FSR work.

**On-farm trials**

Experience with On-Farm Research Trials (OFTs) has been a particularly difficult area on which to reach consensus. Scientists are not comfortable with the lack of experimental control, replications and measurement error, while extension workers question the usefulness of these trials under the wide range of conditions under which they are expected to provide advice and specific recommendations. The work cited in India (Yazman et al 1995) made an effort to overcome these problems and in particular to speed up the time between technology generation and widespread adoption by farmers. The steps cited earlier are aimed at determining which technologies are most appropriate for specific environments (or recommendation domains). OFTs complement on-station research, farm-based demonstrations, and farmer training and extension campaigns. They provide three important advantages over on-station trials:

1. technologies are tested under ‘real world' conditions of the farm environment,
2. farmers have an opportunity to evaluate the technology within their own production systems and
3. researchers and extensionists have the opportunity to incorporate the knowledge, experience and modifications of farmers in the development of technology (Yazman et al 1995).

The adoption process by farmers is sped up and made more responsive and cost-effective by this researcher-extensionist collaboration and by the evaluation and modifications provided by the OFTs. The use of RRAs, as described above, plays an important role targeting the appropriate technology and FS for setting up OFTs.

Collinson (1987) and Mettrick (1993) provide definitions of different types of OFTs:

1. Exploratory Research Trials: These trials are used to test new crop varieties under the environmental conditions of the farmer. Researchers manage all aspects of the trial; when necessary even hiring land from farmers.
2. Adaptive Trials: These incorporate farmers' perceptions into the overall evaluation of new technologies found to be promising in on-station trials, or imported from other places.
3. Verification Trials: In these trials, socio-economic aspects are considered and farmer management of the new technology is taken as a variable. Knipcheer (1986) adds `promotional trials' to the above list basically being demonstrations of new technology.

Within this, we can also distinguish between `researcher-managed trials' and `farmer-managed tests', the latter incorporating socio-economic perspectives more directly into the technology evaluation process.

The book edited by Singh et al (1995) provides a more extensive treatment of FSR/E in all stages as well as a considerable amount of data and results from dairy on-farm trials focusing on feeding systems.

**Change, dynamics and opportunities**

**Impact of economic liberalisation**

The key issue is that the Uruguay Round agreement under the GATT (since transferred to the World Trade Organization) significantly changed the rules governing international trade in agricultural products (John Mellor Associates 1994). These changes affect smallholder dairying in developing countries in a variety of ways: (1) market access and tariffication, (2) export subsidies, (3) domestic subsidies, and (4) sanitary and phytosanitary barriers. In the first category, developing countries are required to reduce the trade-weighted average of tariffs by an average of 24 per cent over 1995-2000. Of particular significance for agriculture in developing countries is that subsidised exports from developed countries must be cut one-third from base (1986-90) levels and budget expenditures on export subsidies by developed countries must be cut by a minimum of 36 per cent during 1995-2000. The volume of subsidised exports must be cut by 21 percent over the same period, (De Boer et al 1996).

Subsidised exports of dairy products has made it difficult for the dairy industries in many developing countries to compete with imports. This has led to slow growth in domestic production and a variety of measures, for example, tariffs, quotas and domestic content rules to lessen competition from imports and promote local production. These policies often are at a very high cost to the treasuries and consumers of developing countries.

Both the USA and the European commitments under the Uruguay Round of GATT are summarised in
Table 3.3 for the main dairy products exported.

**Table 3.3. Export subsidy reductions agreed to under the Uruguay Round of GATT (De Boer et al 1996).**

<table>
<thead>
<tr>
<th></th>
<th>Million ECU of subsidies</th>
<th>Thousand tons of subsidised product</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Union</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter and butter oil</td>
<td>1246</td>
<td>848</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>348</td>
<td>237</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter and butter oil</td>
<td>45</td>
<td>30.5</td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>121</td>
<td>82.5</td>
</tr>
</tbody>
</table>

The figures illustrate the European Union's commitment to drastically release its 'butter mountain'. The impact of these rules, as well as domestic budgetary constraints in developed countries has already markedly reduced stocks of skim milk powder and led to substantial short-term price increases of this product. The longer-term perspective has been summarised by John Mellor and Associates (1994) which projects substantially higher international market prices for dairy products (between 34-84 per cent increase over 15-20 years). Therefore, the longer-term market outlook for developing country producers competing against foreign imports is good. However, higher volatility of prices is following the reduction of stocks that used to be held by developed countries. In addition, local subsidies and quotas in tariffs in developing countries will also decline, thus exposing producers to international markets.

**Need for development of capital markets**

Due to imperfections in the whole system supporting long-term capital markets in developing countries as well as a history of defaults for livestock loans, there is little capital available for smallholder dairying at competitive rates of interest. This has hampered investments in breeding stock, production, processing and on-farm investments needed to support dairying. Government intervention to circumvent these market failures has been expensive and often counterproductive in terms of the need to set up viable, self-financing credit schemes that have a high degree of member control and participation and can provide long-term credit at reasonable cost to dairy farmers.

**Stresses and opportunities**

Stresses and opportunities are created by (1) changes in the input and output markets as reflected by price changes, (2) technological advances and (3) the legal, institutional and policy environment. These dynamics interact; for example, changes in relative prices lead to technological change allowing substitution of more expensive for less expensive resources. Also, increased use of agricultural land for cropping and urban development implies that crop residues become more important for livestock feed. This should stimulate increased research and extension activities on improving the feeding value of this class of feeds.

Some of the major stresses likely to face smallholder dairy producers are now summarised. Dairy development in developing countries, in common with developed countries, is characterised by extensive government involvement, regulations and, often subsidies, both direct and indirect. This pattern is facing...
more stress due to World Trade Organisation conditions, increasing pressure on government budgets and pressure from the processing industry to remove controls and restrictions limiting their opportunities to expand and procure raw products from a greater range of sources. Dairy farmers and, in particular, their organisations need to take advantage of these opportunities with new and innovative approaches managed closer to the grass roots level. Working more closely with processors can also pay dividends.

Gradual improvements of rural support infrastructure, for example, electricity, roads, telecommunications, and water supply, create further opportunities for smallholders by reducing the cost of chilling, transporting, processing and distribution of milk and other products. Refrigerators are spreading to rural areas, expanding the potential market for fresh and frozen dairy products.

The increasing value of women's time and expanding opportunities for employment of women has had mixed effects. Since much of the labour provided for dairy production in developing countries is provided by women (Lourdes 1982), this implies that these tasks will become more costly and the opportunity cost of women's time is increasing. On the other hand, this decreases the amount of household processing women have time for and opens up opportunities for increasing demand of processed dairy products.

There are numerous studies that indicate good long-term prospects for the demand for dairy products. The combination of rapid income growth in countries with large populations of potential consumers and the high elasticity of demand for dairy products has led to rapid growth in demand. The recent adjustments in macroeconomic conditions in a number of countries represent what is largely perceived to be a temporary setback.

Consumption has also expanded due to changes in technology; in particular the rapid growth and availability of Ultra-High Temperature (UHT) milk, which does not require refrigeration until opened. Government policies, targeted towards nutritional improvement through school-milk programmes, have also led to a larger proportion of the population now becoming accustomed to regular milk consumption.

One of the primary stresses on dairy production, both commercial and smallholder, is the increased opportunity cost of land and irrigation water, both caused by increased urbanisation and growth of populations and incomes. In addition the lack of opportunities for secure, remunerative long-term investments has caused surplus capital to be concentrated on the market for land. This had the effect of creating artificially inflated prices relative to their highest opportunity cost in agriculture. This also made agriculture in general, and dairying in particular, less profitable relative to the option of selling the land for speculative or non-agricultural purposes.

Another stress is caused by imperfections in the capital market and in the legal and enforcement mechanisms in developing countries. Dairying is, by nature, a capital-intensive operation, both on the primary production and processing side of the business. Because of technological and market factors, it is also fairly risky. Access to long-term capital at reasonable cost is essential.

The other area of the world that has been subjected to substantial economic and political liberalisation over the past decade is the post-communist nations of Eastern Europe and the Newly-Independent States (NIS) of the former Soviet Union. The process, reforms and restructuring have been so uneven that it is difficult to draw any conclusions for smallholder dairying in this group of countries. Production of dairy products formerly was highly dualistic, with large state farms coexisting with very small household units, where permitted. Individual initiative and the profit incentive resulted in more inputs and management skills going to the private dairy producers. The break-up of state/collective/co-operative farms has been uneven in its scope and distribution but in general, farmers have regained their herds, are free to plant forage and fodder crops and to produce for the market. On the other hand, the precipitous decline in purchasing power and the reduction or elimination of subsidies on dairy products has reduced demand and
consumption levels of dairy products. Growth prospects, both for demand and supply, are good in the medium-to long-term but for the near future, this group of countries will not be significant players in world markets.

Smallholder dairying is also a labour-intensive activity. Therefore, the economic rationale of dairying for farm families is heavily dependent on rural wage rates and the opportunity cost of family labour. While there is evidence of gradually rising rural wage rates in developing countries, seasonal labour shortages are becoming more pronounced as is permanent or temporary off-farm work. The rapid expansion of primary and secondary education in the developing nations will exacerbate this trend very quickly. Even now, many rural areas are characterised by a very uneven age distribution of male populations with a high proportion of males in their prime working age absent from farms at any given time. This places added stress on women, children and the elderly for routine farmwork and low productivity work such as gathering fodder and tending grazing animals. As a high proportion of labour for dairying is already carried out by women and children and since dairying is often a major source of regular cash income and essential food for the household, the impact of these changes in the labour market has so far been moderate. In the medium to long-term, however, labour market dynamics will push dairying towards a semi-to fully commercial mode where incomes will be high enough to compensate for family labour inputs. The size of a `commercial' unit will vary greatly but the trend is already in place.

Policy and project issues

Smallholder dairying operates under a variety of economic policies that directly or indirectly affects the ability of smallholders to save, invest, manage risk, trade and compete. Sound macroeconomic policies first and foremost provide price stability needed for long-term planning of investments, a competitive financial market where savings can be accumulated and channelled to areas with high rates of return and where public sector resources for an efficient rural infrastructure are available. Discrimination against agriculture, in terms of protection of the industrial sector, overvalued exchange rates, excessive allocation of capital and infrastructure to industrial and urban areas, must be reduced.

Reform of the financial sector is also important to promote sustainable financial institutions. Innovative means are being developed which better fit the needs of smallholders and at the same time reduce lending risk, thus lowering the cost of borrowed capital.

The Asian Development Bank (ADB 1993) study on policies and strategies for livestock improvement in developing countries concluded that the primary policy failure was promotion of inappropriate technology. This is reflected in continuing problems experienced in livestock development programmes and projects. These policies often target levels of technology, such as, imported dairy cattle or rapid upgrading of local breeds, which cannot be supported by other inputs, such as, feed and animal healthcare or by current levels of farm management skills. Animals or necessary inputs were often provided free or at subsidised levels, often supported by subsidised loan packages. These projects often failed because of inappropriate technologies, a point stressed in Section 3 of this chapter.

For dairy animals, this is usually reflected in feeding problems. Poor nutrition then increases the animals susceptibility to health problems and physiological stresses, resulting in lower milk production and much longer calving intervals (ADB 1993). This is a particularly acute problem in the humid tropics where tropical grasses create higher costs of energy feed production and costs of supplementary energy and protein feeding increase as the potential productivity index of the animals rises.

Institutional support for smallholder dairy development activities
Institutions that require various levels of support are now set out. Typically, institutions involved in supporting the agricultural sector include (Bawden 1985):

1. Educational and training institutions
2. Agricultural research institutions and experiment stations
3. Logistical and regulating functions including credit, storage, transportation and marketing facilities
4. Institutions providing incentives to increase production and productivity; and
5. Institutions providing extension services.

These can be expanded to include legal frameworks, land tenure and governance of institutions.

An important public policy principle which should be kept in mind when Governments and producers try to develop and apply appropriate technology is the role of the public versus the private sector. Strategies for livestock development planning must be incorporated into an indicative planning framework. The earlier approach to fostering livestock development was based on a broad view of government responsibilities which could include price controls, government-owned and operated feed mills; government breeding and stock multiplication farms; model farms; subsidised inputs, including credit; trade restrictions on movement of animals; government-owned and operated slaughterhouses; provision of animal products to public servants, government-owned livestock ranches and other examples which still persist in some countries.

Such interventions have, in the past, proved costly and counterproductive. It is now generally recognised that the government should restrict its role to four areas which have most of the elements of a `public good' and should be provided efficiently by the government.

1. Animal health, including quarantine services and prevention of endemic diseases
2. Research
3. Extension

Some would add various types of environmental protection to the above.

**Projects**

Dairy development continues to offer opportunities to promote more general rural development objectives. In many situations, the potential exists for income generation and employment expansion at relatively low cost. Potential backward and forward linkage effects are often substantial.

Based on the principle of clearly separating the roles of the public and private sector in dairy development, project assistance should focus on animal health, research, extension, consumer protection and the types of infrastructure typically provided in the public domain. Projects can also assist with provision of credit to private sector participants, including, farmers, agro-industries, processors, and distributors as long as the principles of sound banking, loan recovery and, risk assessment are followed.
Summary and conclusions

The picture described above is mixed regarding prospects for smallholder dairying in developing countries. On one hand, steady increases in demand, a gradual improvement of rural infrastructure and a considerable amount of technology, now available for smallholder dairies presents good opportunities to expand output and income and to make better use of farm resources. Problems of providing credit to smallholders are being tackled in a number of innovative ways. Many of these use a variety of institutions and organisations, often rural-based and relying on traditional social structures, to provide relatively small amounts of credit based on priority needs as established by individuals, family, villages or lending groups. Dairying is often a priority area for such lending and success rates are often outstanding. Intermediation, or the process of gathering surplus funds and lending it to those with credit requirements, is increasingly being recognised, as a function local institutions are able to carry out themselves.

Trade liberalisation will have an uneven impact. While the huge subsidies for developed country dairy products will be gradually reduced, developing countries are also being forced to reduce levels of protection and barriers to competition which have been used to protect local producers and processors. This market liberalisation should, on balance, help smallholders as it will aid market expansion of dairy products, permit lower-cost imports of processing and collection equipment, reduce concentrate feed costs and the costs of other manufactured inputs, such as, supplements, and pharmaceuticals as well as opening opportunities for a more market-oriented sector.

Smallholder dairying does not necessarily require land; in many cases landless labourers operate efficient and profitable dairy enterprises. The ability to spread economic opportunities through dairying should not be neglected. These producers, however, often have experience and a background in dairying, which is not the case in some developing countries. However a number of factors will make it difficult for smallholders in developing countries to produce economic returns from their resources:

Land prices continue to escalate faster (a) than general price levels and (b) than the value of milk produced. This makes farm expansion or acquisition of farmland to be used for dairying uneconomical or beyond the reach of smallholders.

Increased cost of labour (both market rates as well as the opportunity costs of farm family member labour) will make it more difficult to secure attractive returns to family labour devoted to dairying.

Lack of a developed credit market for smallholders in most countries and the high cost of alternative sources often make it uneconomic to invest in capital intensive farm enterprises such as dairying. This impedes investments in improved animals, new technologies, and equipment. Problems with collateral, high costs of loan portfolios for smallholders and risks not easy covered by insurance all lead to high costs.

Trade liberalisation, as summarised earlier, will put increased pressure on high-cost producers of milk and milk products and force smallholders to improve efficiency, cut costs and further rationalise collection, transport, processing and distribution.

Continued technical progress in developed countries, such as growth stimulators and embryo transplants, coupled with persistent genetic improvement through artificial insemination, will continue to provide annual average increases of 1.2 to 1.5 per cent per cow. This will continue to put pressure on these countries to export surplus dairy products when domestic demand stagnates or declines.

References

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap3.html#TopOfPage
Socio-economic aspects of smallholder dairy farmers


Chapter four
Climatic and environmental factors affecting dairy productivity
J. E. Vercoe

Background

Tropical environments can be conveniently sub-divided into two sub-categories: wet tropics and dry tropics. The wet tropics are characterised by high rainfall and predictable rainfall patterns, with one or two annual peaks. The soils in these zones are frequently heavily leached and the soil nutrients are either recycled relatively rapidly or leached to the lower strata. Lush vegetation, with a relatively low N content, accompanies the seasonal rainfall patterns. The dry tropics are characterised by lower average rainfall and extremely variable seasonal and annual rainfall patterns. The geological origins of the soil largely determine its fertility. The natural vegetation may be savannah with a prevalence of annual grasses.

The rainfall drives the environmental features such as humidity, the prevalence and extent of internal and external parasites and, of major importance, the feed supply.

Introduction

The dairy animal is a milk-producing factory which converts nutrients, derived from a variety of dietary constituents, into a complex, marketable and highly nutritious product. In order to do this it must first produce a calf, and then, like all factories, the efficiency of the processing of the raw material (the dietary roughages and concentrates) is of paramount importance. It is determined by the amount of feed eaten, the genotype of the animal and its ability to resist those elements in its environment that operate to reduce the intake of feed or the efficiency with which it is digested and metabolised. There are a number of elements...
in the environment which must be overcome if an animal it is to reproduce and be efficient and highly productive. Major environmental constraints to high productivity in the tropics are ambient temperature and humidity, annual and seasonal availability of feed resources, internal and external parasites and a variety of bacterial and viral infections. The issue of feed resources is covered elsewhere and will not be considered further in this Chapter. The effect of climate, parasites and diseases on production can be minimised either through the use of resistant genotypes or through managerial interventions to the animals' environment. In most cases a combination of these two basic strategies is used.

Of these constraints, the most difficult to combat are those associated with high ambient temperature and humidity encountered in most tropical areas. This is because of the genetic trade-offs that are necessary when attempts are made to combine high milk production potential with high resistance to heat, and the costs involved if the environment is modified using engineering solutions. Controlling parasitic and other diseases is possible using known technologies, even in smallholder dairy systems, provided that there is sufficient economic return to justify the outlay on vaccines, anthelmintics and acaricides. Without doubt, given that feed is in adequate supply, the major problem is in controlling the thermal environment in order to maximise production from the feed available. There is no simple solution to this and the reasons for this will be indicated in this Chapter.

The effect of climate and the environment on animals is complex. For example environments which have similar air temperature and humidity but differ in wind speed will have different effects on the animal in terms of its ability to maintain body temperature. Measurement of these variables and/ or the formulation of an index, tells us nothing about the state of the animal. For this reason, the preferred strategy is to measure the state of the animal, its body temperature, respiration rate and production, and relate this to the conditions that prevail. Measurement of the environmental variables to predict what the likely effects might be on an animal, without prior knowledge of how a particular genotype responds to such environments, can be very misleading. The animal is the best integrator of all the climatic and environmental variables and it is through direct measurements on the animal that the effect of the environment can be most accurately judged.

**Thermal equilibrium**

Dairy cattle, like other warm-blooded animals, function most efficiently in environments where they can maintain their body temperature at a round 38°C. Tissue and cellular metabolism and the underlying biochemical reactions that sustain life and productive functions need body temperature to be maintained within very narrow limits. Relatively small increases in body temperature, for example, one degree Celsius or less, result in detectable, deleterious effects on metabolism and tissue integrity, in particular, the breakdown of body protein and a significant depression in production.

The maintenance of a constant body temperature (usually measured as the rectal temperature), or being in a state of thermal equilibrium, is therefore a prime requirement for productive dairy cattle.

There are two sides to the thermal equation; heat load and heat dissipation. Thermal balance and the maintenance of a constant body temperature require that the heat load and dissipation are equal. Effective management of high producing dairy cattle in tropical environments involves strategies that tackle both sides of the equation; they may reduce the heat load or increase the heat dissipation. The fundamental principle is thus:

Heat load = Heat dissipation (1)
There are several components of heat load, the magnitude and effect of which must be understood if efficient and high milk production are to be achieved by smallholders in tropical environments. These can be divided into two broad categories; metabolic or endogenous heat load and environmental or exogenous load. Endogenous heat load is derived from the heat production associated with the maintenance of basic body processes and the heat production associated with the digestion and metabolism of feed into milk; both of which are related to feed intake and the interrelated level of milk production. The energy cost of milk production is less than the energy cost of growth or fattening and from this aspect, milk production generates a lower heat load per unit of energy produced than growth or fattening processes. The use of bovine somatotrophin, which increases milk production in temperate areas in high producing cows may be less effective in tropical conditions because of the additional heat load generated. Ways in which endogenous heat load can be reduced will be discussed later.

The exogenous heat load is composed of the solar heat load that is either directly encountered or reflected from the ground and surrounding objects, and heat that is conducted and convected through the hair, skin and tissues from the surrounding environment. In the same environment, different animals will receive different amounts of exogenous heat. These differences are associated with differences in coat type and coat colour. Animals with light coloured, sleek coats absorb less heat from the environment than dark coloured woolly-coated animals. The exogenous heat load is composed of energy of different wavelengths which may exert different effects. For the purposes of the present discussion this constitutes an unnecessary complication to the general principles involved.

The exogenous heat load can also be modified in various ways which will be discussed later.

**Heat dissipation**

The dairy cow, like other cattle, dissipates heat by two distinct methods; evaporative and non-evaporative pathways. There are two avenues through which evaporative cooling is effected: sweating and respiration.

Cattle have well-developed sweat glands in the skin but the density and depth of these glands, and consequently their effectiveness as a dissipatory mechanism, varies within an animal (the neck, shoulder and escutcheon regions are better endowed than the flanks and backline) and between animals and breeds. In contrast to human sweating mechanisms which are under cholinergic control. Sweat glands in cattle are adrenergically controlled. As heat load increases and body temperature begins to rise, sweat glands throughout the body surface are synchronously activated, and the overall sweating rate is regulated to maintain body temperature.

If this mechanism is insufficient by itself to maintain normal body temperature, the respiratory pathways are activated and animals will pant, which in some circumstances may be associated with salivation, in further attempts to reduce body temperature. Sweating produces temperature gradients from the body core to the skin and panting reduces core temperature through evaporation in the lungs. The hypothalamus integrates signals from the skin, body core and brain sensors relating to body temperature, and orchestrates the animal's physiological responses. Evaporative cooling from the nasal membranes, adjacent to the hypothalamus, may cool it to some extent and thus moderate physiological responses to high heat loads. In desert adapted species, selective cooling of the hypothalamus by passing inhaled air over the bucchal cavities and membranes is a well-documented way of conserving water in the short-term.

The animal also dissipates heat by radiating heat from its body to the environment and through the other physical pathways of heat transfer, conduction and convection. There are also behavioural responses such as seeking shade and investigating locations and situations where the air movement enhances the effect of evaporative and convective heat dissipatory mechanisms. Other behavioural responses might include,
splashing water and saliva and wallowing, all of which might be exercised at some point in an overall effort to maximise the dissipation of heat under stressful conditions.

Equation 1 can be expanded to reflect the various components of heat load and heat dissipation:

\[ \text{HL}_{\text{met}} + \text{HL}_{\text{env}} = \text{H}_{\text{Devap}} + \text{H}_{\text{non-evap}} \] (2)

where:
- \( \text{HL}_{\text{met}} \) = metabolic heat load;
- \( \text{HL}_{\text{env}} \) = environmental heat load
- \( \text{H}_{\text{Devap}} \) = evaporative heat loss;
- \( \text{H}_{\text{non-evap}} \) = non-evaporative heat loss.

When Heat Load exceeds Heat Dissipation body temperature will begin to rise and the animal will respond in ways that will help it maintain thermal equilibrium and normal body temperature. In the absence of any intervention from the producer, the animal makes adjustments to the components of both sides of the equation in order to achieve this.

**Reducing heat load**

If left to its own devices to achieve thermal equilibrium, an animal will initially seek shade or a cooler spot in its surrounds. It will then commence sweating and increase its respiration rate. If the heat load continues over a period of time at chronic rather than acute levels, the animal will reduce feed intake as a key strategy to achieve thermal balance. Any decrease in feed intake will be associated with a consequent decrease in milk production. Reducing feed intake as a way to reduce heat load is of course incompatible with the needs of the smallholder and the family because it reduces the food security of the household as well as reducing any cash income derived from the sale of milk or curd. The aim of the dairy farmer should be to maintain a low risk level of profitability. This can be achieved by optimising the amount of milk produced from the feed resources that are available, as a result of crop production, or able to be purchased at economic prices.

Indigenous breeds in developing countries are highly heat tolerant relative to the European breeds. This has been achieved partly through having a lower maintenance requirement and as a consequence their genetic potential for milk production is much lower than that of European breeds. The evolution of these breeds has produced a package of attributes that have put a premium on survival, for example, they are resistant to heat and most parasites and have a high capacity to survive when feed is in short supply. They may also have a deep lactation anoestrus which acts to safeguard the cow from the stress of another pregnancy and lactation. It also ensures that the calf at foot has the best possible start in life without competition from a sibling. The ability to survive when feed is in short supply results from their lower maintenance requirement which in turn is correlated with lower metabolic rate. This has a positive impact on heat resistance. It also results in tropical breeds having a lower voluntary feed intake for a given weight, relative to temperate breeds. Metabolic heat load can be reduced therefore, by using indigenous breeds. However, this will be associated with lower milk production and a relatively higher proportion of the feed available being used for maintenance of the animal rather than for milk production.

Metabolic heat load is influenced also by diet. Fibrous roughages of low digestibility produce high levels of heat during digestion. The end-products of digestion of a fibrous diet have high proportions of acetate relative to propionate and butyrate, and there are relatively high levels of heat associated with the metabolism of acetate into other compounds that are used to maintain body processes and manufacture milk. Thus there will be a lower metabolic heat load from concentrates that are readily digestible and result in readily metabolisable end-products such as propionate, microbial protein and probably small
amounts of glucose that escape fermentation in the rumen.

Reducing the environmental component of heat load is largely a matter of construction and engineering. Providing shade, air movement generated through designed air ways and in some cases by the use of mechanical or manually operated fans, water sprays where the additional humidity does not create discomfort rather than relief, and in some cases sprinklers. Costly, specially designed housing for a few dairy cows will be beyond the capacity of most smallholders. Nevertheless, innovative use of space under, or adjacent to, living areas can create cooler areas that are more conducive to reducing heat load than situations in which animals are tethered for long periods in positions that are exposed to levels of solar radiation that are close to maximum.

**Enhancing heat dissipation**

In the early studies of temperature regulation, scientists strove to find an ‘index’ that would describe the impact of environments on the animal's ability to regulate its body temperature. However, as more became known about the complexities of how cattle generate heat and dissipate it to the environment, the more difficult it became to identify such an ‘index’. Even when environmental variables such as temperature, humidity, wind speed, solar heat load, and the availability and intensity of shade, are known, it is still necessary to have information on the genotype, coat type and colour, feed intake and level of milk production, if such an ‘index’ is to be useful in predicting an animal's ability to maintain thermal equilibrium. The search for indices to describe or predict the likelihood of heat stress over a range of environmental conditions has consequently not been pursued.

Evaporative methods of cooling all require an ad libitum supply of fresh, clean water to function maximally and effectively. The immediate response of an animal deprived of water is to stop eating and this has immediate effects on milk production. Non-lactating cattle in environments that cause a one degree C rise in body temperature will increase their evaporative loss from a non-stressed value of around 4 litres per day to 18 litres per day in the case of heat resistant genotypes and 10 litres per day in the case of heat susceptible genotypes. Lactating animals will have higher values than this, possibly by a factor of two or three, and they also have the additional need to replace the water secreted in milk. The latter may be 5-25 litres depending on the level of production.

The various technologies and management practices used to enhance non-evaporative avenues of heat dissipation are similar to those used to reduce heat load. Thus, providing shade and air movement, and maximising the opportunity for radiation and convection losses from the animal. This can be achieved by allowing the animal to be in uncovered locations in the evening and early morning when the animal is likely to be warmer than the surrounding air and objects.

**Effects of heat stress**

The inability to maintain thermal equilibrium and normal body temperature under hot conditions are observed in several ways. Firstly, animals display physical signs of discomfort such as shade seeking, high respiration rate and possibly salivation. Secondly, there will be a decline in feed intake and the efficiency of feed utilisation accompanied by decreases in milk production. Thirdly, there are the unseen effects of high body temperature on physiological and biochemical processes that disrupt hormonal balances and normal function. This result in changes to the oestrus cycle, a reduction in conception rate, depression in milk yield and changes to milk composition.

In cattle of the same genotype, it is the highest producers that first show signs of heat stress and reduced production under hot conditions. Energetically, milk production is the most efficient productive function
with approximately 70 kJ milk produced for every 100 kJ of metabolisable energy. This compares with around 48 kJ/kJ for growth and 61kJ/kJ for fattening. The maintenance of body tissues and functions has the highest efficiency at around 80+ kJ/kJ. Therefore, there is a smaller metabolic heat load produced per kJ of product by milk.

The magnitude of the reduction in milk yield under hot conditions depends on the following factors:

1. environmental conditions (air temperature and wind speed, humidity and radiant heat load)
2. composition and quality of the diet (digestibility, roughage: concentrate ratio, end-products of digestion)
3. access to fresh water and shade
4. genotype (adaptability and milk yield potential)
5. level of management skills.

Unadapted genotypes that have a high genetic potential to produce milk (for example, Holstein-Friesian) are most severely affected. They will be affected in environments which have no effect on the production of relatively high producing adapted genotypes (for example, Sahiwal). Although the genetic potential for milk production for Holstein-Friesian and Sahiwal are different, in hot environments realised production may not differ or may even favour the Sahiwal for some situations. It is also true that relatively high producing adapted breeds, such as the Sahiwal, may be out-performed by local smallholder cattle in situations where the feed supply is limiting and management skills are poor.

In encouraging milk production amongst smallholder farmers, once market outlets are established, one of the prime considerations has to be to match the genotype to the prevailing climatic, feeding and management skills that prevail. The need to balance all the components of the system for maximum efficiency will be mentioned later.

Other environmental constraints (parasites and diseases)

Although the environmental constraints most difficult to deal with are those related to the climate and feed resources, internal and external parasites along with some bacterial and viral diseases must also be considered in smallholder production systems.

Internal and external parasites are likely to be more important in production systems that incorporate a grazing component. In `cut and carry' systems, feed is manually cut in fields or along roadsides and the dung is removed from where the animals are housed and used for fertiliser or fuel. Consequently, the life cycles of most helminths and ticks (Boophilus spp, Theileria annulata) and to a large extent buffalo fly, are disrupted to such an extent that they are no longer a significant cause of production loss in adult animals. Other biting insects, for example, Culicoides, may be a source of irritation but are unlikely to need any special control measures. In young animals, depending on the manner in which calves are cared for, there may be a need for occasional anthelmintic treatment and examination for ticks.

In situations where parasites are a problem, the local breeds are likely to be resistant to the parasites. Bos indicus breeds carry fewer ticks than European Bos taurus breeds and they are also more resistant to the species of gastrointestinal helminths that prevail in the tropics than introduced breeds. Because of their resistance to parasites, local breeds have a most important role in the development of a dairy industry based on smallholders. In any crossbreeding program the local breeds will be the base populations that
will confer the resistance traits required in the early stages of an up-grading program; up-grading in terms of the genetic potential as well as the nutritional and managerial inputs.

Parasites such as the screw-worm fly are rarely a problem because the cattle in smallholder systems are observed closely every day and can be treated quickly and effectively when an emergency arises.

Much is known about the bacterial and viral infections that may impact on the production of smallholder systems. Constraints to the successful control of these diseases are not technological but relate to the availability and cost of treatment. As markets for the milk from smallholder farmers become more sophisticated and infrastructures improve, then the provision of vaccines and antibiotics will become more prevalent and more affordable to smallholders. This will initially be through co-operatives, and probably with Government support, but as markets develop and begin to assert their commercial `pull', private veterinary enterprises will provide these goods and services.

The tropical dairy cow

Because of the constraints to production in the tropics, associated with climatic, nutritional and other environmental variables, inadequacies in the financial system, and deficiencies in the types of managerial skills that are required in sophisticated dairy production systems, it is important to have a totally integrated production package that balances all aspects of the production system. Matching and balance are required between the technological inputs and the socio-economic conditions that prevail at the time.

Therefore, the genotype and its management must be matched to:

1. climatic conditions that exist
2. available nutrition (whether home grown or supplemented with purchased feeds)
3. the degree of challenge from parasites and diseases
4. the level of managerial skills
5. availability and cost of labour to feed, milk and market the product and its priority in relation to other demands on the household
6. availability of finance
7. availability and access to profitable markets.

Therefore, no single tropical dairy type can be defined as the `best'. The `best' type will be determined through consideration of the above factors and is likely to vary from use of local dairy types through to high grade Holstein-Friesian. The dairy industry in tropical countries will evolve as the conditions change, even amongst smallholder farmers, but climatic factors will ultimately be the limiting factors to high levels of production. Unless there is a large investment into climate controlled conditions, the very high producing cows of European *Bos taurus* origin will always be less efficient producers of milk in the tropics than inherently heat tolerant breeds, developed through crossbreeding between local and exotic breeds and selection within those populations for high production.

Similarly, it is unlikely that the use of local breeds as pure breeds will be the most profitable in all but the very poorest of situations, where feed is inadequate, parasites and diseases are uncontrolled and levels of production barely fulfil household needs. The upgrading of the environment and management skills are
essential correlates to the upgrading of genotype.

**Suggested Reading**


Chapter five
Dairy breeds and selection
V. K. Taneja

Introduction
Dairy cattle
Breeds
Some new crossbreeds
Performance potential of dairy cattle breeds
Selection schemes
Grading up to local cattle with improved indigenous breeds
Selection within indigenous breeds
Crossbreeding
Synthesis of crossbred strains
Buffalo
Breeds
Performance potential of buffalo breeds
Selection schemes in buffalo
Artificial insemination and embryo transfer
References and suggested reading

Introduction

Genetic potential of dairy breeds in the tropics is low yet hardly exploited because the common objective has been to meet the limited milk requirements of the household. The levels of animal husbandry in most tropical countries, except Israel and Australia, are low. The breeds perform under harsh and unfavourable climates, varying between equatorial (rainfall above 2032 mm/annum and a temperature range of 21-32°C) to tropical arid (low and erratic rainfall less than 500 mm/annum and temperature extremes of 0-60°C). Large variations in climate and vegetation, and shortage of feeds across the region are major constraints to dairy production. Field recording in most tropical countries is almost negligible and virtually no information on the performance potential of cattle and buffalo breeds in their native environments is available. Change in cattle and buffalo population dynamics, in relation to calves born, disposal patterns through sale of heifers and cows in a village has never been looked into. Against this background, the development of breeds has produced distinct characteristics suited to different conditions.

Dairy cattle

Breeds

Domestic cattle belong to the family Bovidae, sub-family Bovinae and can be classified into *Bos taurus*
and *Bos indicus*. They have 30 pairs of chromosomes, interbreed and are distributed throughout the tropics. The third type, *Bibos banteng* (Bali cattle) and *Bibos frontalis* (mithun) belong to genus Bibos and are present only in south and south east Asia.

Domestication of *Bos taurus* cattle took place some 8000 to 9000 years ago and Homitic longhorn and shorthorn types are believed to be their ancestors. The origin of *Bos indicus* breeds (humped cattle) was in western Asia (Payne 1970). Both humped and humpless cattle were introduced to Africa from western Asia and into America and Australia from Europe by the immigrants.

European cattle *Bos taurus* were introduced in the tropics to be raised as pure-breds and crossbred with indigenous breeds. As a result of crossing of native cattle with European dairy breeds, large numbers of crossbreeds have been produced in various tropical countries, which are being used in selection programs. *Zebu* *Bos indicus* cattle were introduced into United States in the nineteenth century for crossbreeding with European breeds. Breeds resulting from crosses are used in the southern regions of north America and tropical south America.

Most of the cattle breeds in the tropics evolved, through natural selection, for adaptability and survival to local environments. Often, breeds resemble each other with slight morphological differences, but because of constant inbreeding in one locality, independent breeds have evolved. In general, the cattle from drier regions are well built and those from heavy rainfall areas, coastal and hilly regions are of smaller build.

The physical characteristics, utility and production performance of cattle breeds available in tropical and sub-tropical regions of the world have been described by Payne (1970). Most indigenous cattle breeds in the tropics are multipurpose (milk, meat, draught) and that only a few breeds have good milk potential. Physical and economic parameters for some of the important indigenous dairy breeds and new crossbred types developed in the tropics are discussed below:

**Damascus**

Animals of this breed are found in Syria, Turkey, Iraq, Cyprus, and Egypt and are crosses between humpless and humped cattle. The breed appears to have been developed in the Ghuta, the oasis of Damascus and then spread to other regions. Animals are of medium size with a narrow body and long thin legs. The coat colour is light or reddish to dark brown. The head is long and narrow with short horns. The hump is absent; the dewlap is relatively well-developed particularly in males. The udder is medium sized with long thin teats. Damascus is one of the best milch breeds in western Asia. The females yield between 1500 and 3000 kg in a lactation period of 200 to 300 days with four to five per cent fat.

**Gir**

Although, the breed is native of Gujarat, it is also found in Maharashtra and Rajasthan States in India. The peculiar features of the breed are a protruding-broad and long forehead, and pendulous forward turned ears. The popular colour is white with dark red or chocolate-brown patches distributed all over the body. Entire red animals are also encountered although it is usually mottled with yellowish-red to almost black patches. Gir cows are good milkers and milk yield ranges from 1200 to 1800 kg per lactation. The age at first calving varies from 45 to 54 months and the intercalving period from 515 to 600 days. The Gir breed has been exported to other parts of the world. In Brazil where large herds are found, it is known as Gyr. Brazil has also evolved a strain called Indubrasil which is a cross between Gir and Kankrej. Gir animals are highly prized by Brazilian breeders who have created a breed society. Gir animals have also been exported to the USA, especially Texas, Florida and Lousiana states.
**Hariana**

The native breeding tract of this breed encompasses large parts of Rohtak, Hisar and Gurgaon district of Haryana State and is a prominent dual-purpose breed of north India. It has been extensively used in grading up non-descript cattle particularly to improve their draught capacity in the Indo-Gangetic plains. Hariana cattle are characterised by a long and narrow face, flat forehead and well marked bony prominence at the centre of the poll. Horns are small. The muzzle is usually black. Eyes are large and prominent. The udder is capacious and extends well forward with a well-developed milk vein. The teats are well developed, proportionate and medium sized. Good specimens of cows yield up to 1500 kg of milk per lactation. The age at first calving is 40 to 60 months depending on management and feeding conditions. The intercalving period varies from 480 to 630 days. Males are powerful work animals.

**Iraqi**

The breed is found in southern Iraq and resembles Red Sindhi. It is a medium-sized breed with short legs. The coat colour is golden to bright bay. The hump and dewlap though prominent are not large. Average milk yield per lactation is around 600 kg and calving interval 400 days. The breed is extensively being used in upgrading with temperate dairy breeds.

**Kankrej**

The home tract of this breed is Gujarat (India). It is the heaviest of the Indian breeds. The animals have a broad chest, straight back and a well-developed hump. The dewlap is moderately developed. These cows are average milkers and yield about 1400 kg under farm conditions while yield under village conditions is low. The age at first calving varies from 45 to 47 months and the intercalving period from 486 to 510 days. Bullocks are fast and powerful draft animals. This breed has been exported to a number of countries to be raised as pure-bred and for crossbreeding. Today excellent herds of this breed are found in Brazil where it is known as Guzerat. Many beef breeds in some Latin American countries and southern states of the USA have some inheritance of Kankrej.

**Lebanese**

This breed is found in Lebanon and Syria. It is a short-bodied medium size animal with short, strong legs. The coat is yellowish to reddish brown, reddish brown or black in colour with black tips. The skin is medium in thickness with short hairs. The horns are of medium length and white in colour. The dewlap is well developed. The milk yield varies between 1000 and 2500 kg per lactation.

**Mauritius Creole**

This is a humpless polled breed. The animals are small, neat and compact. The predominant coat colours are white, white with brown, dun or dark markings and brown. The skin is thin and un-pigmented. The dewlap and sheath are very small. The breed is primarily used for milk production. Milk yield varies between 2225 and 3481 kg in a lactation length of 180 to 300 days.

**Ongole**

The native tract of this breed is the Guntur district of Andhra Pradesh, India. This is essentially a large muscular breed suitable for heavy draft work. An average milk yield of 600-1000 kg is common. Good specimens yield up to 1500 kg per lactation. The age at first calving is 38 to 45 months and the
intercalving period 470 to 530 days. Excellent specimens of this breed have been exported to Brazil where large herds now exist. They are known as Nellore in Brazil. This breed has also been exported to Sri Lanka, Fiji, Indo-China, Indonesia, Malaysia and the United States. The famous Santa Gertrudis breed evolved in Texas, USA includes Ongole blood.

Rathi

Rathi cattle are named after a pastoral tribe called Raths who lead a nomadic life. The home tract of this breed lies in the heart of Thar desert. Rathi breed, is a mixture of Sahiwal, Red Sindhi, Tharparkar and Dhanni breeds with a preponderance of Sahiwal blood. The animals are of medium size with a symmetrical body and a short and smooth body coat. Their udder is well developed with a prominent milk vein. The females are docile and good milkers (1325 to 2093 kg per lactation). Calving interval ranges between 445 and 617 days.

Red Sindhi

The home tract of this breed is Karachi and Hyderabad districts of Pakistan. Red Sindhi animals, though small in size are very good milkers. They have a compact frame with round dropping quarters. They are coloured red with the shades varying from dark red to light. White patches are sometimes seen on dewlap and occasionally on the forehead. Milk production in the institutional herds ranges from 1250 to 1800 kg per lactation. Age at first calving is 39 to 50 months and the calving interval 425 to 540 days. Red Sindhi animals have also been exported to many other parts of the world including Sri Lanka, Tanzania, the Philippines, the United States, Malaysia, Iraq, Burma and Indo-China. Red Sindhi females have been used in crossbreeding with Brown-Swiss and Jersey to develop new breeds such as Karan Swiss and Jersind in India.

Sahiwal

The breeding tract of this breed is Montgomery district in Pakistan which is now named as Sahiwal. This is the best dairy breed of the Indian subcontinent. It is a comparatively heavy breed with a symmetrical body and loose skin, when compared with Red Sindhi which it closely resembles. The animals are usually long and fleshy and of heavier build. They are coloured reddish dunn or pale red, sometimes flashed with white patches. Muzzle and eyelashes are light in colour. A number of herds of this breed are maintained in India. The milk yield ranges from 1400 to 2500 kg per lactation. The age at first calving ranges from 37 to 48 months and the calving interval from 430 to 580 days. Sahiwal animals have been exported to Sri Lanka, Kenya, the West Indies and many other Latin American countries. A new breed called Jamaica Hope has been evolved using Sahiwal x Jersey crossbreeds.

Sudanese

These cattle (Kenana, Butana) resemble in confirmation to the Red Sindhi and Sahiwal, but vary in coat colour. Blue-gray colours predominate in the Kenana breed. In Butana, the coat is usually red though mixed coloured animals are found. The head is long and coffin shaped. The ears are long and semi-pendulous. The hump is cervico-thoracic to thoracic in position. The dewlap is large and prominent. This is primarily milk cum draught breed suited to dry areas. Kenana type is considered the better milker.

Tharparkar

The original habitat of this breed is Tharparkar district in the Province of Sind, Pakistan. The breed is also
found in the adjoining tracts in Rajasthan State in India, particularly around Jodhpur and Jaisalmer where excellent milch specimens are found. This is a medium-sized compact breed. The males are also good draught animals. The milk yield in cows ranges from 1800 to 2600 kg per lactation, age at first calving is from 38 to 42 months and the intercalving period is from 430 to 460 days.

**Some new crossbreds**

**Australian Friesian Sahiwal (AFS)**

The AFS, is a dairy breed evolved through use of Sahiwal bulls on Holstein Friesian cows through interbreeding and selection among successive generations by the Queensland Department of Primary Industries. The breed has 50 per cent Sahiwal and 50 per cent Holstein Friesian inheritance. The AFS under Queensland conditions produced 2749 kg milk and 115 kg of fat as against 3670 kg milk and 141 kg fat produced by Holstein Friesian (Tierney 1985). The production of AFS cows improved under wet tropical conditions and these produced 124 per cent of the milk and 141 per cent of the fat produced by their *Bos taurus* herd mates. This suggested that AFS provided a real alternative to *Bos taurus* breeds in hot humid conditions of Australia and other tropical countries. Breed improvement for milk through progeny testing is in progress.

**Australian Milking Zebu(AMZ)**

The AMZ developed by the CSIRO contains between 20 and 40 per cent *Bos indicus* blood (Sahiwal, Red Sindhi) and 60 to 80 per cent from Jersey. Hayman (1974) has described the formulation of the breed. Little difference for milk production between Jersey (1944 kg) and AMZ (1917 kg) heifers, under conditions of optimum management, was observed. Moderate estimates of heritability for milk (0.23) and total fat (0.27) for the AMZ population suggested that selection would be effective. The results of comparison of AMZ with Guernsey and Friesians for milk and total fat showed that AMZ (3304; 146 kg) were comparable with Guernsey (2913; 124 kg) and Friesian (4165; 138 kg). There is also some difference in the degree of heat tolerance between AMZ and *Bos taurus* cattle; exposure to 36°C for Friesian and 40.5°C for AMZ resulted in depressions of milk yield by less than five per cent in AMZ and by 30 per cent in Friesians (Hayman 1977).

**Frieswal**

Friesian x Sahiwal crossbreeds with Friesian inheritance between 3/8 and 5/8 are being interbred using semen of 5/8 Friesian crossbred bulls into a breed development program. The new breed has been named ‘Frieswal.’ The 5/8 Friesian bulls have been produced through nominated matings using proven semen of Holstein Friesian bulls on 3/8 Friesian crossbreeds. This collaborative project between the Indian Council of Agricultural Research and Military Farms in India, aims to progeny test 40 Frieswal bulls per year. The averages for the total and 300 first lactation milk yield were 2729.9 and 2629.5 with a lactation length of 326.0 days. The peak yield was 12.2 kg and average weight at first calving was 381 kg.

**Jamaica Hope (JH)**

The Jamaica Hope breed developed in Jamaica contains about 80 per cent Jersey, 15 per cent Sahiwal and five per cent Holstein breeding. In conformation, the breed is similar to Jersey, although larger. The coat colour varies from fawn, brown and gray to black. The breed has been developed for dairying under humid tropical conditions. The average 305 day milk yield in the recorded herds was 2737 kg with a mean butter fat yield of 130 kg and a butter fat content of five per cent. The performance however, at Bodles
butter fat yield of 130 kg and a butter fat content of five per cent. The performance however, at Bodles farm was 3218 kg. The large variation in performance was due to variation in husbandry practices; yield levels averaged 2905, 2000 and 1623 kg respectively for good, mediocre and poor herds. The mean age at first calving ranged from 33.1 to 42.4 months and calving interval from 371 to 466 days. The heritability and repeatability estimates for milk yield were reported to be 0.35 and 0.77, respectively. The breed has a remarkable degree of tolerance to anaplasmosis and piroplasmosis as it was exposed to tick infestation through its formative stage. The JH cattle have been exported to other Caribbean and some Central and South American countries.

**Jersindh**

Indigenous breeds viz. Kankrej, Gir, Hariana, Sahiwal and Red Sindhi were crossed to Holstein Friesian, Brown-Swiss, Jersey and Guernsey at the Agricultural Institute, Naini, Allahabad. The idea was to increase milk yield of indigenous breeds. The results of crossbreeding suggested that Red Sindhi x Jersey crosses had the most desirable traits for Indian conditions. These include, small body size, better adaptability and high fat percentage. The Jersey crossbreeds between 3/8 and 5/8 have been interbred and named as `Jersindh'. Similarly, 3/8-5/8 Brown-Swiss x Red Sindhi crosses have been interbred and named as `Brown-Sind'. Jersindh crosses gave milk yield between 1557 and 1861 kg in first lactation. The breed has shown deterioration over the years mainly because of small numbers and being confined to the Institute farm.

**Karan Fries**

This breed has been evolved through crossbreeding between Tharparkar and Holstein-Friesian at the NDRI, Karnal, India. The breed has 50 per cent inheritance from Friesian, and is extremely docile. The average age at first calving is 30 to 32 months and the milk production is around 3700 kg with 3.8 to 4.0 per cent fat. The intercalving period is 400 to 430 days.

**Karan Swiss**

Karan Swiss evolved from crossing American Brown Swiss bulls with Sahiwal and Red Sindhi cows at the National Dairy Research Institute (NDRI), Karnal, India. Brown-Swiss inheritance is around 50 per cent. The colour of the breed is red dun. It resembles Sahiwal in its body size and general appearance, and the dewlap is pendulous as in the case of Sahiwal. The hump is almost non-existent, the barrel is long and deep, the naval flap is from tight to slightly loose. Eyes are full, ears small, oblong and hairy from the inside. The neck is of medium size. The legs are proportionate in size and well set apart. The udder is of good size, wide, deep and long. The udder is mostly bowl shaped; teats are cylindrical pointed or round and are of medium size. The milk veins are well developed and tortuous. The males have powerful shoulders. The average age at first calving was 32 months; the first lactation yield was 2564.7 kg with 4.2 to 4.4 per cent fat. The total milk yield based on pooled lactations was 3257.3 kg with an overall calving interval of 395.5 days.

**Mambi**

This breed has been developed from crosses of Holstein-Friesian x zebu in Cuba and has 3/4 Holstein-Friesian and 1/4 zebu inheritance. Milk yield is around 2500 kg. The age at first calving and calving interval are 32 months and 439 days, respectively.

**Non-descript Cow**
Most cattle in the tropics are of a non-descript type. These are named after their location and do not possess uniform breed characteristics. They have poor growth rates, late maturity and low milk production. Little information on the non-descript cow is available. Average milk yield is 340 kg (123 to 996 kg) with lactation length ranging from 124 to 394 days (Bhat and Mukandan 1979).

Pitanqueiras

This breed contains 5/8 Red Poll and 3/8 zebu inheritance and has been developed in Brazil. The average age at first calving and calving interval are 35 months and 414 days respectively. Milk yield averages 2780 kg and mature body weight is 422 kg.

Siboney

This breed has 5/8 Holstein-Friesian and 3/8 zebu inheritance and has been developed in Cuba. Milk yield averages 2897 kg. The age at first calving and calving interval are 31.3 months and 405 days, respectively.

Sunandini

Under an Indo-Swiss Project in Kerala which started in 1963, local non-descript cows were crossed with Brown-Swiss bulls. The crosses with 50 per cent, 75 per cent and 62.5 per cent Brown-Swiss inheritance were produced. The crossbreeds with 62.5 per cent Brown-Swiss inheritance were mated, followed by selection to synthesise a new breed named `Sunandini'. Sunandini animals under field conditions give a lactation yield of 1351 kg in 305 days. Sunandini bulls are being progeny tested for milk using performance recording under field conditions. A total 323 Sunandini bulls have been evaluated and 42 bulls declared proven.

Taylor

The `Taylor breed' of cattle was said to have been evolved near Patna, using crosses of taurus bulls (Shorthorn and Channel Island bulls from the United Kingdom) with local cows by Mr. Taylor. Their coat colour is red, gray or black and they do not possess a hump. No published records on the performance of this breed are available. The breed is almost extinct.

Performance potential of dairy cattle breeds

Performance potentials of dairy breeds in the tropics are presented in Table 5.1. The information is based on the performance in organised farms as records on performance in the native environments are hardly available. A large variation in performance parameters were due to variation in location, management inputs, periods, as well as genetic variation between herds.

Age and weight at first calving

Indigenous dairy breeds, except some in Africa, are late maturing and the potential for early sexual maturity is not yet fully known. Only 1.9 per cent of the Hariana heifers at the Indian Veterinary Research Institute, calved between 30 and 33 months and 21 per cent calved by 39 months of age (Dadlani et al 1969). Around 75 per cent of Tharparkar heifers calved by 35-45 months of age and of that number only 12 per cent calved at less than 30 months (Dutt et al 1974). Similarly, 19 per cent of Sahiwal heifers
calved by 34 months of age, 67.4 per cent from 35 to 44 months and 13.5 per cent beyond 44 months (Wahid 1976). Sahiwal bulls are slow breeders and are serviced only after 30 to 36 months of age, under field conditions. However, at organised farms with better conditions of feeding and management and with training, the bulls can be initiated into semen collection after about two years. The typical active life of a bull in the village varies from four to eight years, while at the organised farms it varies from eight to ten years (Wahid 1976). Low and medium heritability estimates for age at first calving have been reported indicating that some genetic improvement in this trait could be made by selection.

**Table 5.1. Production performance of some of the indigenous dairy cattle breeds in tropics.**

<table>
<thead>
<tr>
<th>Breeds</th>
<th>Weight at maturity (kg)</th>
<th>Age at first calving (months)</th>
<th>Milk production per lactation (kg)</th>
<th>Lactation length (days)</th>
<th>Calving interval (days)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASIA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sahiwal</td>
<td>301 - 544</td>
<td>37.4 - 48.8</td>
<td>972 - 2523</td>
<td>184 - 354</td>
<td>405 - 571</td>
<td>4.3 - 5.2</td>
</tr>
<tr>
<td>Red Sindhi</td>
<td>317 - 454</td>
<td>39.0 - 50.9</td>
<td>835 - 1869</td>
<td>231 - 345</td>
<td>435 - 562</td>
<td>4.5 - 5.2</td>
</tr>
<tr>
<td>Rathi</td>
<td>295 - 386</td>
<td>40.0 - 52.0</td>
<td>1325 - 2129</td>
<td>306 - 331</td>
<td>486 - 617</td>
<td>3.7</td>
</tr>
<tr>
<td>Kankrej</td>
<td>430 - 650</td>
<td>45.0 - 47.0</td>
<td>576 - 1850</td>
<td>351 - 351</td>
<td>486 - 510</td>
<td>-</td>
</tr>
<tr>
<td>Gir</td>
<td>319 - 568</td>
<td>43.3 - 61.5</td>
<td>1126 - 1859</td>
<td>230 - 394</td>
<td>426 - 541</td>
<td>4.5 - 4.6</td>
</tr>
<tr>
<td>Ongole</td>
<td>363 - 591</td>
<td>36.0 - 54.0</td>
<td>613 - 1590</td>
<td>217 - 279</td>
<td>485 - 637</td>
<td>5.1</td>
</tr>
<tr>
<td>Hariana</td>
<td>287 - 499</td>
<td>41.0 - 60.0</td>
<td>656 - 1783</td>
<td>209 - 315</td>
<td>434 - 631</td>
<td>4.3 - 5.3</td>
</tr>
<tr>
<td>Tharparkar</td>
<td>293 - 544</td>
<td>37.5 - 53.0</td>
<td>911 - 2449</td>
<td>240 - 326</td>
<td>399 - 474</td>
<td>5.0 - 5.2</td>
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<tr>
<td>Iraqi</td>
<td>272 - 363</td>
<td>33.0 - 45.0</td>
<td>609 - 1035</td>
<td>193 - 277</td>
<td>391 - 454</td>
<td>-</td>
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<tr>
<td>Damascus</td>
<td>136 - 318</td>
<td>-</td>
<td>1500 - 3000</td>
<td>190 - 300</td>
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<td>4.0 - 5.0</td>
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<tr>
<td>Lebanese</td>
<td>230 - 350</td>
<td>-</td>
<td>1000 - 2500</td>
<td>-</td>
<td>-</td>
<td>4.0 - 5.0</td>
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<tr>
<td><strong>AFRICA</strong></td>
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<tr>
<td>Creole</td>
<td>343 - 500</td>
<td>30.0 - 31.0</td>
<td>500 - 3481</td>
<td>180 - 300</td>
<td>365 - 420</td>
<td>4.6 - 5.1</td>
</tr>
<tr>
<td>Boran</td>
<td>259 - 680</td>
<td>35.0 - 52.0</td>
<td>454 - 1814</td>
<td>139 - 313</td>
<td>334 - 420</td>
<td>4.1 - 6.8</td>
</tr>
<tr>
<td>Sudanese</td>
<td>250 - 500</td>
<td>24.0 - 54.0</td>
<td>454 - 2723</td>
<td>168 - 339</td>
<td>365 - 730</td>
<td>4.7 - 5.5</td>
</tr>
</tbody>
</table>

A wide range in weight at first calving in tropical breeds exists (120-680 kg). Large variation was a reflection of variation in management regimes, genetic merit of the stock and age at calving. Heritability estimates of around 0.3 have been reported for this trait. Most of the Asian dairy breeds attained the mature weight between 30 and 35 months and there were little differences for mature weight among various breeds. The growth pattern to weight at maturity was linear with average daily gain varying between 200 and 332 g.

**Calving interval**

Average calving interval in tropical breeds varied between 334 and 730 days. Sahiwal, Tharparkar, Red Sindhi and Deoni had short calving intervals (around 15 months) while Hariana, Gir and Rathi had long calving intervals. African breeds had, in general, shorter calving intervals than the Asian breeds. Calving interval is reported to have low heritability and can be improved through better nutrition and early breeding.
Milk yield

Milk yield in tropical breeds showed wide variation. A few breeds like Sahiwal, Tharparkar, Red Sindhi, Rathi, Gir, Kankrej, Damascus, Sudanese, White Fulani and Boran had good milk yields (1000-3000 kg). However, most other breeds were dual or triple purpose (milk, meat, draught) having qualities of survival under low input, harsh climate or even resistance to disease. The heritability estimates for milk yield in indigenous breeds averaged around 0.25 to 0.30 thus suggesting that a large complement of genetic variability for milk production existed in these breeds.

Selection schemes

The breeding objective of increasing productivity per animal has been attempted through:

1. grading up of local cattle with improved indigenous breeds
2. selection within the indigenous breeds, and
3. crossbreeding of native cattle with temperate dairy breeds.

Grading up of local cattle with improved indigenous breeds

Upgrading programs bring the level of inheritance of the local stock to 15/16 of the breed used for upgrading in four generations which takes approximately 30 years. The entire population at the end of 30 years in the region could be, for example, Sahiwal, with a production level between 1800 and 2000 kg per lactation.

The Red Sindhi, Sahiwal, Gir, Kankrej and Ongole breeds have been used in grading up in various parts of the tropics and sub-tropics for improving milk production. This is due to their tick resistance and heat tolerance qualities. The method has helped to increase yield levels especially in the Indian sub-continent where good indigenous dairy breeds were available and used in the grading program. A genetic study in Kenya of grading up of East African Zebu to the Indian Sahiwal covering over 25 years, revealed a substantial increase in milk production in various Sahiwal grades (31-64 per cent) over East African Zebu. The increased production in Sahiwal grade cows was associated with an increased length of lactation, and a slightly larger calving interval than in East African Zebu (Mahadevan et al 1962). Sahiwal grades proved adaptable to conditions of high altitude and high rainfall.

Red Sindhi bulls were used for improving the local Indian dairy cattle in Malaysia. Over the period 1950 and 1971 milk yield among Red Sindhi and its crosses was lower than milk yield among local cows which was attributed to wide variation of Red Sindhi imported from Pakistan(Sivarajasigam and Mukerjee 1975).

Initial experiences in various tropical countries grading local cattle with European dairy breeds were not encouraging. The higher crosses with exotic inheritance of 3/4 or more, faced problems with climatic stress and disease and had lower yields than those with intermediate inheritance. These experiences led to the use of indigenous breeds to reduce the level of exotic inheritance. The model of alternate breeding of crossbreeds with exotic and indigenous breeds led to the development of a number of grades (1/16 to 15/16) which makes it difficult to provide advice to smallholders compared to stabilized new breeds. The major limitations of grading up programs are low yield levels of the improver breed used, long generation interval in indigenous breeds and the time required for generations to grade up to the level of improver breeds.
Selection within indigenous breeds

Selection for higher milk yield in indigenous cattle breeds through culling of inferior cows and selection of young bulls on dam's yield and body conformation is the origin of animal breeding. In most herds, culling of cows was practised after three or four lactations. Thus progeny of inferior cows need to be called also, a difficult task in smallholder conditions.

Genetic gains for milk yield in some of the herds of indigenous dairy breeds have been found to be negative or non-significant and have large standard errors (Narain and Garg 1972). Negative genetic gains were due to use of genetically inferior bulls in the herd. Analysis of the NDRI herd in India from 1936 to 1971 revealed no evidence of any statistically significant genetic gain in first lactation milk yield (Gurnani and Nagarcenkar 1982). Acharya and Lush (1968) reported the genetic progress in milk production in Hariana cattle to be 10 kg per year. A progeny testing program in Sahiwal breed in Kenya led to an increase in overall herd average from 1042 kg milk per cow and lactation in 1965, to 1630 kg in 1972. Use of Sahiwal as purebreds in arid areas and in crosses with European breeds in semi-arid and coastal areas of Kenya was recommended.

Impact analysis of a bull selection program, based on pedigree and type, in a purebred Sahiwal herd in Pakistan revealed that out of 30 sires, only seven bulls produced daughters with milk yield above their dams (Ahmed et al 1972). Although, these bulls were selected from high yielding dams on the basis of pedigree and type, the progeny test information indicated that most of them carried a poor sample of genes from their mother. These studies suggested that pedigree selection may be used only as an aid to selection in the young. However, the final selection of bulls for intensive use by artificial breeding should be based on rigorous progeny test information, a high number of generations and thousands of cows. It is difficult to create measurable improvement from the small numbers that can be maintained on a farm, even state farms.

The major limitations of selection programs for improvement of indigenous cattle breeds for milk production in the tropics were low levels of milk production in the indigenous breeds; absence of performance recording with the farmers' animals, and poor spread of AI in most tropical countries. Assuming an annual genetic gain of one per cent per year, it would take approximately 100 years to double the milk production of a herd with an average lactation yield of 1000 kg. Much faster progress in milk production is necessary to support the increasing costs of milk production and increased milk demand of an ever increasing human population in the tropics.

Barring some improved indigenous breeds like Sahiwal, Gir, Red Sindhi, Rathi, Tharparkar, Damascus, other cattle breeds may not be economical in this time frame for commercial production, even under semi-intensive production systems.

Crossbreeding

Crossbreeding of indigenous tropical breeds with temperate dairy breeds is undertaken to combine high milk yield and early maturity of European dairy breeds with hardiness, disease resistance, and adaptability of local cattle. Initial crossbreeding experiments had setbacks due to outbreaks of rinderpest and other killer diseases to which European breeds are particularly susceptible. Control of these diseases with prophylactic vaccines allowed planned crossbreeding experiments to be taken up in countries such as, India, Pakistan, Sri Lanka, the Philippines, East Africa, West Indies, southern United States and Australia. These crossbreeding experiments clearly demonstrated that crossbreeds were better producers of milk than indigenous breeds and were more adaptable to the tropics than pure-bred exotic breeds.

The crossbreeding experiments were designed to answer questions, such as the importance of native...
The crossbreeding experiments were designed to answer questions, such as the importance of native breeds in crossbreeding; relative superiority among exotic breeds; optimum level of exotic inheritance and, effects of inter-breeding among crossbreeds and level of heterosis. The results of crossbreeding experiments in various tropical countries have been reviewed by many, including Taneja and Bhat (1986), Cunningham and Syrstad (1987), Syrstad (1989) and McDowell et al (1996). Some indicative results are presented in Table 5.2.

Table 5.2. Least squares mean for some lifetime parameters in half-breeds at Izatnagar (India).

<table>
<thead>
<tr>
<th>Genetic groups</th>
<th>Total milk yield (kg)</th>
<th>Total number of days in milk</th>
<th>Total number of days in herd</th>
<th>Number of lactations completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friesian x Hariana</td>
<td>12323+191</td>
<td>1794+19</td>
<td>3675+36</td>
<td>4.64+0.19</td>
</tr>
<tr>
<td>Brown Swiss x Hariana</td>
<td>9666+244</td>
<td>1774+25</td>
<td>3606+46</td>
<td>4.58+0.25</td>
</tr>
<tr>
<td>Jersey x Hariana</td>
<td>9530+240</td>
<td>1710+24</td>
<td>3382+45</td>
<td>4.71+0.61</td>
</tr>
</tbody>
</table>

The following conclusions emerge from the analysis of various crossbreeding experiments:

a) significant reduction in age at first calving and calving interval was observed in crossbreeds. The increase in milk yield in crossbreeds (first as well as lifetime yield) over the indigenous breeds was two-to-three fold depending upon the exotic and indigenous breeds used, level of exotic inheritance, availability of inputs and climatic conditions.

b) Holstein crosses with improved indigenous breeds (Sahiwal, Red Sindhi, Gir and Tharparkar) were superior to crosses from other native breeds or non-descript cattle, thus suggesting that improved native breeds have some role to play in crossbreeding.

c) Holstein crosses were superior to other temperate breed crosses for growth and production while Jersey crosses had better reproductive efficiency. The rank order of exotic breeds in terms of milk output was Holstein, Brown-Swiss, Red Dane and Jersey.

d) Exotic inheritance, at around 50 per cent, was ideal for growth, production and reproduction although production in higher grades in most of the studies fell short of theoretical expectations. Grading up therefore to a total replacement of genes will not lead to higher levels of production in cattle (Taneja et al 1979).

e) Declines in milk production from the \( F_1 \) to \( F_2 \) generation was due to diminished heterosis in part. Large declines in some experiments were due to poor quality crossbred bulls used. In most of these experiments progeny tested superior sires were used to produce \( F_1 \) progeny, while no selection among \( F_1 \) sires was practised. Part of the decline, therefore, due to non-selection of \( F_1 \) sires was expected. The need for vigilance, excellent records, and resources is paramount for efficient upgrading programs.

f) Under free choice feeding, the crossbreeds (half-breeds, 3/4 with two exotic breeds) gave 30 to 60 per cent more milk than their contemporaries under general management. Management and feeding norms for crossbreeds therefore need to be laid down in order to achieve the potential of crossbreeds.

**Synthesis of crossbred strains**

Interbreeding among crossbred populations has mostly been at 50 per cent level (two breed cross) barring...
a few experiments where interbreeding was done at 5/8 (two breed cross) and 3/4 exotic (three breed cross) inheritance (Syrstrad 1989; Taneja 1995). Declines in milk yield were mostly attributed to lack of selection of F₁ bulls as against progeny tested bulls to produce F₁ crossbreeds, deterioration in management over time, presence of little heterosis and partial breakdown of epistatic combinations. Very high culling rates in crossbred males (40-70 per cent) due to poor libido, semen quality and freezability would leave little for selection. The increase in population size over the years, at most of the farms, was not proportionate to housing facilities and land resources. This also resulted in poor performance of F₂ and subsequent crosses. The need for population-wide programs is indicated from these experiences.

In the Indo-Swiss Project in Kerala (India), where interbreeding occurred at 5/8 Brown Swiss level (1/2 BS x 3/4 BS), there was no difference in milk production in 5/8 (2367 kg) and 5/8 interbreeds (2357 kg). The 5/8 interbreeds (Mathew et al 1986)) had even lower ages at first calving (994 days) and calving interval (400 days). The emphasis, while on developing new cattle breeds from crossbred populations, should be on producing the bulls through nominated matings then selecting the best for extensive use through artificial breeding to achieve genetic gains of 1.5 to 2.0 per cent per year.

The option of using crossbreeds for developing new breeds in countries with diverse climates and rapid changing economic conditions may not be practicable. By the time, the breed is evolved, farmers may need types of cattle different from those already developed. With ever increasing costs of inputs and experience, smallholders will increasingly want crossbreeds with higher levels of European blood and higher yield levels. As a result large herds of European dairy cattle have now been established in many tropical countries for commercial dairying and smallholders are asking for crossbreeds with higher milk yield levels. In view of the high performance of Holstein crosses and changing socio-economic conditions, it would be essential that crossbreeds have a larger proportion of Holstein breeding, and other breeds like Jersey should be introduced in small proportions to widen the gene pool and to take advantage of early maturity and improved reproduction. Such a crossbred base should be used in development of new breeds. In situations where breeding objectives are likely to change quickly, it would be desirable to continue the system of criss-crossing using both European and native breeds and the grades produced depending upon the potential of the area. This system would also have an advantage of genetic progress made through selection in parental breeds used in crossing.

**Buffalo**

The domestic or water buffalo (*Bubalus bubalis*) belong to the family bovidae, sub-family bovinae, genus bubalis and species arni or wild Indian buffalo. Buffalo are believed to have been domesticated around 5000 years ago in the Indus Valley. The water buffalo can mainly be classified as river and swamp type. The domestication of swamp buffalo took place independently in China about 1000 years later. The movement of buffalo to other countries both east and westwards has occurred from these two countries. Some of the well-known dairy breeds of buffalo found in India and Pakistan are Murrah, Nili-Ravi, Kundi, Surti, Jaffarabadi, Bhadawari, Mehsana, Godawari and Pandharpuri. Despite potential advantages, little attention has been paid to buffalo improvement programs.

**Breeds**

**Bhadawari**

This breed is found in Agra (Bhadawari Tehsil) and Etawah districts of Uttar Pradesh and Gwalior district of Madhya Pradesh. The body is of medium size and of wedge shape. The head is comparatively small, the legs are short and stout, the hooves black, the hindquarters uniform and higher than the forequarters.
The tail is long, thin and flexible with black and white or pure white markings reaching up to fetlock. The body is usually light or copper coloured which is peculiar to this breed. The udder is not well developed and teats are of medium size. The average milk production is 800 to 1000 kg with very high fat content (10-13 per cent). The bullocks are good draft animals with better heat tolerance. The average adult body weight of female and male is 386 and 476 kg, respectively.

**Egyptian**

Egyptian buffalo are blackish gray in colour. Horns vary from lyre to sword shaped. Head is long and narrow with long and drooping ears. The chest is deep but not very wide. Hooks are wide apart, prominent and higher than pins. The rump is sloping and tail setting is low. Body weight usually is 400-500 kg. The average milk yield in organised farms ranges from 1300 to 2000 kg.

**Godavari**

Godavari breed has been developed from crosses of native buffalo with Murrah bulls. The breed has attained uniformity and almost reached the production level of Murrah. The home tract of this breed is Godavari deltaic areas in Andhra Pradesh, India. The animals are medium sized with compact body. The colour is predominantly black with a sparse coat of coarse brown hair. The head is clean-cut with lean face, convex forehead and prominent bright eyes. The horns are short, flat, curved slightly downward, backward and then forward with a loose ring at the tip. The chest is deep with well-sprung ribs. The barrel is massive and long with straight back and a broad level rump. The udder is medium in size. The tail is thin and extends below the hocks with or without a white switch. Godavari buffalo are reputed for high fat with daily average milk yield of 5 to 8 kg and lactation yield of 1200 to 1500 kg. The best animals even produce around 2000 kg in a lactation. The animals breed regularly and have a short calving interval compared to Murrah. They are hardy and possess good resistance against the majority of the prevailing diseases.

**Iraqi**

Iraqi buffalo are widely distributed, the major concentration being in Baghdad, Basra, Amara, Diwaniya, Hilla and other towns, where they are used for milk production. There is great diversity in colour, which varies from slate black to almost white. White patches on the head, legs and tail are common. Horns are generally sickle shaped. The face is slightly dished. The withers are high, and the croup and haunch bones prominent. The body is generally elongated. The udder in good specimens, is large, carried well back and has large well-placed teats. Milk yield varies from 1600 to 2500 kg in a lactation period of 200-250 days.

**Jaffarabadi**

This breed is found in Gir forests of Kathiawad and is mainly concentrated in Kutch, and Jamnagar districts of Gujarat State. The body is long, massive and fatty. The dewlap in females is somewhat loose and the udder is well developed. The head and neck are massive. The forehead is very prominent. The horns are heavy, inclined to droop at each side of the neck and then turning up at points into an incomplete coil. The colour is usually black; animals of gray and copper colour are also seen. The average milk yield is 1000 to 1200 kg. Some good specimens yield up to 2500 kg of milk in a lactation. These animals are mostly maintained by traditional nomadic breeders called Maldhairs. The bullocks are heavy and used for ploughing and carting. The average adult weight of female and male is 454 and 590 kg, respectively. Under optimum inputs, they may weigh 800 and 1000 kg.
Kundi

The Kundi breed is distributed in the forest tract along the river, Indus, in the rice-growing region of north Sindh and in the swampy and rice tracts of Karachi and Hyderabad districts of Pakistan. Although, Kundi has been described as a distinct breed, some breeders still considered it a geographical variant of Murrah. Kundi animals are generally jet black (85 per cent) although light brown are not uncommon (15 per cent). Horns are thick at the base, inclined backward and upward and end in a moderately tight curl. The forehead is slightly prominent, the face hollow and eyes are small. Hind quarters are massive. Mammary glands are capacious with prominent milk veins; teats are squarely placed. Kundi buffalo are smaller than Nili-Ravi with adult weight of 320-450 kg.

Mehsana

This breed has been developed from crosses between Murrah and Surti and is present in Mehsana, Sabarjanda and Banaskanta districts of Gujarat state. Animals are of medium size with low set deep body. The head is longer and heavier. The horns usually are less curved at the end compared to Murrah but are longer and could be of irregular shape. The udder is well shaped. The colour is usually black to gray, with white markings often on face, legs or tail-tip. The milk yield is 1200 to 1500 kg per lactation. The females are persistent and regular milkers. The intercalving period ranges between 450 and 550 days. The bullocks though slow are good for heavy work. The average weight of mature female and male is 430 and 569 kg, respectively.

Murrah

The breeding tract of Murrah breed is Rohtak, Hisar and Jind districts of Haryana and Nabha and Patiala districts of Punjab in India. These animals have long been selected for milk and curled horns. The breed has a massive body; neck and head are comparatively long, horns short and tightly curved. The hips are broad, and fore- and hindquarters drooping. The tail is long reaching up to the fetlocks. The colour is usually jet black with white markings sometimes found on tail, face and extremities. The udder is well developed. The average milk yield per lactation is 1500 to 2500 kg. The age at first calving is 45-50 months in villages but in well managed herds it is 36 to 40 months. The intercalving period is 450-500 days. The body weight of an adult female ranges from 430 to 500 kg and that of a male 530-575 kg. The bullocks though slow are powerful.

Nili-Ravi

The Nili and Ravi, though earlier referred to strains of Murrah were described as separate breeds in ICAR bulletin No. 46(1941). The Nili refers to blue water of river Sutlej. Ravi gets its name from river Ravi. However, both Nili and Ravi are no longer considered as two but only as one breed i.e. Nili-Ravi. The breed is native of Sahiwal District of Pakistan and is also found in Sutlej valley in Ferozpur District of Punjab state (India). Skin and hair colour of Nili-Ravi are usually black although brown is not uncommon. Wall eyes and white markings on forehead, face, muzzle, legs and tail switch are common. The head is elongate, bulging at top and depressed between eyes. The frame is medium sized. The horns are small, coiled tightly and circular in cross-section. The neck is long, thin and fine. The navel is very small. The tail is long touching the ground. The udder is well developed. The milk yield is 1500 to 2300 kg per lactation. The intercalving period is 500 to 550 days. The age at first calving is 45 to 50 months. The bullocks are good for heavy trotting work. The average adult female and male weigh around 450 and 600 kg.
Pandharpuri

Pandharpuri is an important buffalo breed in south east Maharashtra (India). It is a medium sized animal having long narrow face, very prominent and straight nasal bone, comparatively narrow frontal bone and long compact body. Typical characteristic of this breed is its horns which are very long, curved backward, upward and usually twisted outwards. The neck is comparatively long and thin. Udders of lactating buffalo are medium sized, compact and somewhat hidden between hind quarters. The tail is long and just reaching below hock. The switch of the tail is usually white while hooves are black in colour. The body colour varies from light to deep black. In general the animals are docile in temperament.

Surti

The breeding tract of this breed is Kaira and Baroda districts of Gujarat, India. The body is well shaped and medium sized; the barrel is wedge shaped. The head is long and eyes prominent. The back is straight. The horns are sickle shaped, moderately long and flat. The tail is fairly long. The colour is black or brown. The peculiarity of the breed is that there are two white collars, one round the jaw and the other at the brisket. The milk yield ranges from 900 to 1300 kg. The age at first calving is 40 to 50 months with an intercalving period of 400 to 500 days. The breed is famous for early maturity and efficiency of milk production. The bullocks are good for light work.

Swamp

Although large variation in colour, conformation and body size exits, no distinct breeds have been reported. The swamp buffalo are concentrated mainly in south east China, Myanmar, Malaysia, Laos, Cambodia, Thailand, Indonesia, Philippine, and Vietnam. The skin colour is gray, dark gray to state blue. White animals occur frequently. Animals have swept back horns and are similar in appearance across the countries except the size. The horns grow laterally and horizontally in young animals and curve round in a semi circle as the animals gets older. Animals are massively built, heavy bodied with large belly. The forehead is flat; orbits are prominent with a short face and wide muzzle. They weight from 300 to 400 kg when fully grown. Swamp buffalo are primarily used as work animal in paddy cultivation, for pulling carts and hauling timber in jungles. Milk yield is 1-2 kg per day.

Performance potential of buffalo breeds

Information on mature body weight, age at first calving, milk yield, lactation length and calving interval for various buffalo breeds is given in Table 5.3. A large number of references have been screened to generate the range and these have not been listed as they would be numerous. Large range in averages is because of the performance being for various periods/years, locations and lactations.

Body weights and growth rate

The growth rate from birth to 36 months, in general, was linear across the breeds. The maximum growth rate was during birth to six months and the rate of relative growth declined with age (Bhat and Taneja 1987). The overall average monthly gain from 0-36 months for large breeds was around 12 kg. The results of body weight gain suggest that period up to one year of age could be economically utilized in feed lot for obtaining maximum growth rate. It seems that present potential of the species is around 500 g per day under medium input and 900 g under high input. Moderate to high heritability estimates for body weights up to 30 months suggest that body weights could be improved through selection.
Table 5.3. Production Performance of some of the dairy buffalo breeds in the tropics(figures in parenthesis are the range of values reported).

<table>
<thead>
<tr>
<th>Breeds</th>
<th>Weight at maturity (kg)</th>
<th>Age at first calving (months)</th>
<th>Milk Production per lactation (kg)</th>
<th>Lactation length (days)</th>
<th>Calving interval (days)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murrah</td>
<td>461 (446-567)</td>
<td>43.8 (40.5-55.1)</td>
<td>1805 (1276-2272)</td>
<td>303 (269-351)</td>
<td>451 (420-513)</td>
<td>6.1-8.3</td>
</tr>
<tr>
<td>Nili-Ravi</td>
<td>533 (454-567)</td>
<td>41.2 (37.9-43.0)</td>
<td>1833 (1585-2164)</td>
<td>324a (296-385)</td>
<td>509a (422-579)</td>
<td>6.5</td>
</tr>
<tr>
<td>Surti</td>
<td>319-413 (47.2-55.4)</td>
<td>50.5 (47.2-55.4)</td>
<td>1278 (1126-1552)</td>
<td>293 (261-342)</td>
<td>528 (468-664)</td>
<td></td>
</tr>
<tr>
<td>Bhadawari</td>
<td>(346-467)</td>
<td>48.7 (46.0-51.4)</td>
<td>1009 (976-1040)</td>
<td>(276-330)</td>
<td>(454-489)</td>
<td>8.0</td>
</tr>
<tr>
<td>Kundi</td>
<td>(320-575)</td>
<td>1208-2000</td>
<td>316-322</td>
<td>413-592</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Mehsana</td>
<td>(335-567)</td>
<td>46.8 (44.2-54.5)</td>
<td>1610 (1308-1838)</td>
<td>294 (267-314)</td>
<td>492 (457-526)</td>
<td>7.4</td>
</tr>
<tr>
<td>Egyptian</td>
<td>(369-535)</td>
<td>38.2 (37.0-39.9)</td>
<td>1412 (1078-2112)</td>
<td>286 (254-314)</td>
<td>415-650</td>
<td>6.1-7.4</td>
</tr>
<tr>
<td>Iraqi</td>
<td>-</td>
<td>37.5</td>
<td>1342</td>
<td>255</td>
<td>408</td>
<td>7.5-9</td>
</tr>
</tbody>
</table>

a. First lactation average.

On the basis of body size and weight, Murrah, Nili-Ravi, Jaffarabadi, Godawari and Egyptian buffalo could be classified as large; Surti, Pandharpuri, Mehsana and Bhadawari as Medium and Kundi as small size breeds.

Reproduction

Although buffalo continue to come in heat regularly in all months, the proportion was higher from October to January and lower from April to July. The conception rates during summer and humid months (April to September) were also low which was due to poor semen quality of buffalo bulls. It has been reported that hot-humid months affect the process of spermatogenesis of male buffalo adversely. The use of frozen semen during these months is recommended to overcome the lower conception rates.

Calvings were maximum (15.4 per cent) in the month of September and minimum (3.7 per cent) in June. Around 77 per cent of the calvings took place during July to January (the most calving season) and only 23 per cent during February to June (the least calving season) indicating that the buffalo are seasonal breeders. The average number of services per conception ranged from 1.5 to 3.0. In general, heifers took more services than pluriparous buffalo.

Age at first calving

A large variation in age at first calving across the breeds was noted, it being around 60 months in village...
A large variation in age at first calving across the breeds was noted, it being around 60 months in village buffalo. The averages of age at first calving in Murrah, Nili-Ravi, Egyptian and Pandharpuri buffalo were between 38 and 44 months while that in Surti and Bhadawari buffalo were between 46 and 54 months. The heritability estimate for the trait varied between 0.26 and 0.37.

Calving interval

The first calving interval in Murrah, Nili-Ravi and Surti buffalo varied between 480 and 570 days. Subsequent calving intervals were shorter (430-547 days) than first calving interval. Longer calving intervals are associated with higher lactation yield. Such an association was expected since prolonged calving intervals were the result of long lactation period, due probably to late conception which was directly influenced by feeding, management and heat detection practices. The genetic variability in calving interval was negligible; hence the reduction in calving interval can be achieved through better management, nutrition and feeding.

Milk yield

The average first lactation milk yield in Murrah and Nili-Ravi buffalo (1540 and 1867 kg) were higher than the averages for Bhadawari, Mehsana, Pandharpuri and Surti buffalo (926-1375 kg). Average milk yield in Nili-Ravi buffalo in Pakistan (1969 and 2731 kg) were higher. It was reported that around 1 per cent of the buffalo at the government farms had yield more than 4000 kg (Cady et al 1983). This proportion of high yielding buffalo suggested reasonable opportunity for selection of dams to produce bulls. Comparative performance details of Nili-Ravi breed of Pakistan, Murrah of India and Egyptian buffalo (Table 5.4) revealed that 38 per cent of all lactations in Nili-Ravi had more than 2700 kg of milk as against 14 per cent of all lactations in Murrah and 6 per cent in Egyptian buffalo. The milk yield per day of calving interval in Nili-Ravi, Murrah and Egyptian was 4.6, 3.9 and 3.0, respectively (McDowell et al 1995).

An increase in milk yield over the lactations was noted with a peak in fourth lactation. More than 50 per cent of the buffalo left the herd by the end of 4 lactations and that between 1 and 3 per cent completed 10 lactations (Patro and Bhat 1979; Cady et al 1983). Percentages of lactations terminated due to health and reproductive problems and death were around 30 per cent each in lactations 1 and 2.

Although, Nili-Ravi and Murrah breeds on average completed 3 lactations, some studies reported, the average number of lactations completed in Murrah to vary from 4.4 to 5.8 with lifetime total yield 8914-9994 kg (Dutt and Taneja 1994) and 4.5 to 5.6 lactations in Nili-Ravi buffalo (Cady et al 1983). The average number of lactations completed and lifetime milk yield in Surti (3.72 and 4960 kg) and Iraqi (4.35, 5696 kg) were low (Juma et al 1991 in Kulkarni 1995).

Table 5.4. Comparative performance of Nili-Ravi breed of Pakistan, Murrah of India and Egyptian Buffalo (adapted from McDowell et al 1995).

<table>
<thead>
<tr>
<th>Trait</th>
<th>Nili-Ravi</th>
<th>Murrah</th>
<th>Egyptian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at first calving (mo)</td>
<td>46.7</td>
<td>46.8</td>
<td>38.3</td>
</tr>
<tr>
<td>Weight at first calving (kg)</td>
<td>529</td>
<td>467</td>
<td>432</td>
</tr>
<tr>
<td>Lactation milk (kg) 1st</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparative performance evaluation of various buffalo breeds clearly demonstrated that Nili-Ravi and Murrah were on the top. Mehsana (Murrah x Surti crosses) and Godawari (Murrah x non-descript) were close to Murrah. The next in ranking would be Egyptian, Bhadawari and Jaffarabadi are believed to have an advantage of high fat content although total yield was low.

Although, the first lactation milk yield is the most commonly used selection criteria in dairy buffalo, the economic merit of dairy animals is also influenced by many other characters like age and weight at first calving. Efforts therefore were made to identify some simple measure of milk production efficiency which takes into account the variations caused by factors like lactation length, calving interval and age at first calving, has higher heritability than that of milk yield and has high genetic correlation with milk yield. Some measures of milk production efficiency developed and studied are; milk yield per day of age at first calving, milk yield per day of lactation length and milk yield per day of calving interval.

Most of the heritability estimates for first lactation milk yield in Indian, Pakistani and Egyptian buffalo breeds were between 0.08 and 0.23 The heritability estimates for milk yield per day of first lactation length were higher (0.29-0.33) than first lactation milk yield. The genetic correlation between milk yield...
per day of first lactation length and first lactation yield was high (>0.9). This suggested that selection for milk yield per day of lactation length would result in higher genetic improvement than expected from selection for first lactation milk yield (Bhalaru and Dhillon 1978; Dutt and Taneja 1994).

**Milk composition**

Buffalo milk has comparatively more fat (7.6 per cent) and total solids (18.0 per cent) than zebu or European cow (Table 5.5). The monthly fat percentages were significantly influenced by stage of lactation. The fat percentage showed a continuous increase from first to tenth month. Differences in fat percentage attributed to breed exists; the fat content being 12.6 per cent in Chinese and 8.95 per cent in Philippine buffalo. Murrah breed (6.9-8.5 per cent) has higher fat content than Nili-Ravi buffalo. Large breed differences for fat per cent in milk were also due to yield level, stage of lactation and type of feeding.

**Table 5.5. Composition of buffalo and cow milk (FAO 1977; Rao and Nagarcenkar 1977).**

<table>
<thead>
<tr>
<th>Species</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Lactose (%)</th>
<th>Total Solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egyptian</td>
<td>7.96</td>
<td>4.16</td>
<td>4.86</td>
<td>17.91</td>
</tr>
<tr>
<td>Chinese</td>
<td>12.60</td>
<td>6.04</td>
<td>3.70</td>
<td>23.20</td>
</tr>
<tr>
<td>Carabaos</td>
<td>10.35</td>
<td>5.88</td>
<td>4.32</td>
<td>21.54</td>
</tr>
<tr>
<td>Murrah</td>
<td>7.38</td>
<td>3.60</td>
<td>5.48</td>
<td>17.24</td>
</tr>
<tr>
<td>European cow</td>
<td>3.90</td>
<td>3.47</td>
<td>4.75</td>
<td>12.82</td>
</tr>
<tr>
<td>Zebu cow</td>
<td>4.97</td>
<td>3.18</td>
<td>4.59</td>
<td>13.45</td>
</tr>
<tr>
<td>Crossbred cow</td>
<td>4.00</td>
<td>3.46</td>
<td>4.88</td>
<td>12.83</td>
</tr>
</tbody>
</table>

The per cent fat, per cent ash and per cent solids not fat were moderately heritable (0.29-0.41) while per cent protein was highly heritable (0.74). The repeatability estimates were high. The correlation between milk yield and milk constituent percentages were negative and ranged between 0.20 and 0.77. The genetic correlation among milk constituents however were positive (0.3-1.0). These results suggested that selection for milk yield would lower milk constituent percentages and vice-versa. Although, the increase in milk yield will decrease the milk constituents percentage, the total fat, protein and SNF yield would increase as all yields are positively correlated with milk yield.

**Selection schemes in buffalo**

Around 65 per cent of the river buffalo are of desi type and do not belong to the defined breeds. Improvement in these non-descript buffalo was attempted through grading up with defined breeds; Murrah, Nili-Ravi, and Surti were used in the grading program in the Indian sub-continent where river buffalo predominate. Although no scientific evaluation of these schemes has been made, large proportionate increase in share of buffalo milk over time suggest the effectiveness of grading up schemes.

In Sri Lanka, grading up of local buffalo with Murrah and Surti from India, resulted in a significant increase of approximately 290 per cent in milk yield over the local buffalo, where the milk production was around 355 kg per lactation (Jalagte 1982). Murrah were superior to grade Murrah only by 241 kg (16 per cent) in milk production with no apparent difference in lactation length. Assuming a generation interval of 6 years and a turn over of 5 generations, one could expect an improvement of approximately 34 kg milk per year through the grading up program, which is highly satisfactory.
In the defined breeds the selection in the initial years was done through culling of low yielders and selection of bulls on the basis of body confirmation and dams milk yield. Government farms for important buffalo breeds with herd size of around 300 breedable females and 10 bulls were established for production and testing of bulls for improving milk yield in them. The results of these studies have not been encouraging mainly because of small herd size, poor accuracy of sires breeding values and non-availability of semen freezing facilities at most of the farms. The analysis of the selection experiments at organized farms in India (Reddy and Taneja 1982) and Pakistan (Khan 1994) for genetic gains in milk revealed highest contribution from dam to son path (82-84 per cent) and dam to daughter path (11-15 per cent) and that contribution from sire to son and sire to daughter path was almost negligible. Apparently, the emphasis while selection both cows and bulls was mostly on their dam's performance. This was expected in the absence of progeny testing. Annual genetic gains in 300 day first lactation milk yield were estimated to be 15.9 kg (0.99 per cent of the herd average of 1611 kg) and 3.3 kg (0.17 per cent of the herd average of 1879 kg). Relatively low genetic gains for milk yield may be due to the subjective basis of selection, less genetic variability and low culling rates etc. For achieving higher genetic gains, the only alternative is to initiate and strengthen the progeny testing programs at least for important dairy buffalo breeds. Progeny testing programs for Murrah, Surti and Mehsana in India and Nili-Ravi in Pakistan have been in existence and evaluation of bulls is being made using appropriate sire evaluation methodologies. Progeny testing program for Mehsana and Murrah in India have large field base involving farmers animals and envisage producing 100 completed first lactation records of progenies per bull. Milk production and fat percentage of each daughter is measured once a month till it completes lactation. The best linear unbiased estimates of top ten sires (28 to 90 daughters) ranged between + 67.1 and + 152.7 kg. The overall sample average first lactation yield of daughters was 1917 + 38 kg and age at first calving 42.9 + 8.1 months (Trivedi 1997).

Semen of buffalo is less reliable than that of cattle. The approach, therefore has to be of producing large numbers of quality males through nominated matings and screening on their breeding value. Field recording programs with farmers participation on a co-operative basis is important for buffalo upgrading and requires a buffalo population of around 10,000. All buffalo in the program should be identified, registered and a system of performance recording developed. Inputs like health care, artificial breeding, feeds and fodder and marketing should be built into the system. Sequential selection among males should be following growth rate, production records of dams and semen testing. The bulls finally clearing the semen test should be used in test mating and those with higher breeding value used for breeding. Such programs of progeny testing should be linked and coordinated at national level. Research inputs for improving AI and semen quality in buffalo and methodologies for sire evaluation under field conditions should be made available.

A maximum genetic gain of 1 to 1.5 per cent in milk yield using intense selection of bulls under progeny testing is possible. Multiple ovulation and embryo transfer (MOET) technique offers potential to increase selection response for milk yield in buffalo. There is a large genetic diversity available in buffalo breeds; crossing between them needs to be attempted to combine desirable genes of Murrah and Nili-Ravi for high milk and medium fat; Bhadawari for greater heat tolerance and high fat, and Surti for regularity of breeding in a new breed synthesis program.

**Artificial insemination and embryo transfer**

The artificial insemination (AI) envisages collection of semen from the male and its introduction in the female system at the most appropriate time. The technique involves care and rearing of males from birth to maturity; collecting, grading, preserving and transporting of the semen, and inseminating semen into females. AI in domestic animals gained importance with increase in knowledge of male and female reproduction, also concept to breed improvement and to check the spread of disease. Scientific studies on...
reproduction, sire concept to breed improvement and to check the spread of diseases. Scientific studies on biology, fertilisation, development of extenders, endocrine aspects of male and female reproduction, semen preservation and storage led to use of AI routinely especially in cattle and buffalo both at organised farms and under field conditions in most developed countries while its use under field conditions in tropics is still limited. Acceptance of AI in buffalo is lower than that in cattle and is mainly attributed to non-availability of good quality semen, silent heat, and poor quality buffalo semen in summer months.

The spread of AI brought in focus the concept of identifying good sires both in terms of fertility and milk yield. Need of good male calves born to high yielding dams led to the establishment of bull mother farms (elite herds) and recording system an essential input for progeny testing program. Development and spread of AI programs has many advantages. The most important one is the use of good sire to produce many daughters in different agro-climatic zones to improve the future generations. With the advent of frozen semen, it is now possible to transport semen to far off places and also use the semen even if the bull is dead. The AI also helps in prevention of spread of reproductive diseases through use of disease free bulls. In addition, sexual health control of females and extension program aimed at improving productivity can be operated through AI service. On the other hand, AI has brought into focus the use of few sires on a large female population resulting in increased levels of inbreeding. AI at early and late heat is not only unfruitful but causes infections in cervix and uterus and results in repeat breeding. Proper heat detection and AI at proper time are very essential to achieve higher conception rate. The success of AI lies in reduced time interval between semen collection and its placement into female. Processes of evaluation, dilution, preservation and transport should be systematically and effectively monitored so that the time factor is minimized. The time factor directly influences the viability of spermatozoa and thus the fertilizing ability.

Although a good network of infrastructure for artificial insemination in some Asian and Latin American countries has been developed over time, the conception rates in cattle under field conditions varied between 15 and 25 per cent. AI services offered are mostly at fixed places and that by the time the animals are brought for AI, either the heat period is over or animal has not get bred for other reasons. High temperature and direct sunlight in tropical countries is responsible for low fertility especially among buffalo bulls. From April to September, the buffalo males produce semen of very in different quality. The poor technical knowledge of the inseminator also contributes to low fertility.

Although conventional breeding technologies viz. selection and mating systems have contributed significantly in genetic improvement of livestock in developed countries, the pace in developing countries was slow because of poor spread of AI and non-availability of males in requisite numbers. Infrastructure for recording of data in the field conditions is negligible. Progeny testing as being practiced in developed countries therefore cannot be adopted in tropical countries poorly developed in Animal Husbandry. Herd size with the farmers is small (1-2 cows/buffalo). In view of above, the technology of superovulation and embryo harvesting, splitting has high potential and far-reaching genetic implications for spectacular progress in tropical countries. Embryo transfer (ET) is a composite technology which involves superovulation, oestrus synchronisation, artificial insemination, embryo recovery, embryo transfer and cryo-preservation and micro manipulation of embryos. The most obvious impact of using ET has been to increase selection intensity among females by increasing the number of offspring from genetically superior females. It is especially more important in species with low reproductive efficiency such as cattle and buffalo which produce less than one calf per year. With superovulation and embryo transfer, it is now possible to have between 9-12 calves per year. Records are even available to have as many as 50 calves from a single donor. Technologies of embryo collection, freezing and transfer both in cattle and buffalo have now been standardized and should be made an integral component of sire production and sire testing program.

References and suggested reading

http://www.ilri.org/InfoServ/Webpub/foldocs/SmHDairy/chap5.html#TopOfPage
References and suggested reading


Dairy breeds and selection


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Chapter six
Milking buffalo
V.D. Mudgal

Introduction

The world population of buffalo (*Bubalus bubalis*) has been estimated at over 140 million head (FAO 1991). Of these, 97 per cent are found in Asia and the Pacific region, mainly in India (75 million), China (21 million), Pakistan (14 million) and Thailand (6 million). About 98 per cent of buffalo in the region are raised by small farmers owning less than two hectares of land and less than five buffalo. The buffalo originated in the Indo-Gangetic Plain, thrived throughout Asia and became a symbol of life, religion and endurance. Water buffalo were in the service of humans as early as 2500-2100 BC. Buffalo have been classified into two distinct classes: swamp and river (Mudgal 1992).

The swamp buffalo of China, Thailand, the Philippines, Indonesia, Vietnam, Burma (Myamar), Laos, Sri Lanka, Kampuchea and Malaysia, are mainly used as draught animals particularly in rice cultivation. Very few swamp buffalo are reared for milk because they only produce 1.0 to 1.5 litres of milk per day. In contrast, the riverine breeds of the Indian sub-continent are mainly raised for milk production since they yield six to seven litres of milk daily.

Milk production

Buffalo are the second largest source of milk supply. Of the 38.5 million tons of world milk production, India produces 23.6 million and Pakistan 10.5 million tons (FAO 1991, Table 6.1). While the world cattle population over the last 18 years has risen by less than one per cent per year, the buffalo population has gone up by two per cent per year, with higher rises in India (3.5 per cent), Pakistan (5.4 per cent), China (3.7 per cent), Vietnam (4.8 per cent) and Nepal (2.0 per cent). The higher population growth rate of buffalo can be attributed to better conversion efficiency compared to the local cattle. Ninety-five per cent of India's milk is produced from bovine diets based on crop residues like wheat straw, paddy straw, maize and millet stovers, supplemented with concentrates made out of agricultural by-products such as, oil cakes, rice polish and molasses. In India buffalo account for 33 per cent of the milk animal population and

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45 per cent of milk.

Table 6.1. Buffalo milk production (unit: 1000 tonnes).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>26</td>
<td>21</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>0.5</td>
</tr>
<tr>
<td>Bhutan</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>China</td>
<td>1390</td>
<td>1800</td>
<td>1850</td>
<td>1900</td>
<td>1938</td>
<td>3.7</td>
</tr>
<tr>
<td>India</td>
<td>17358</td>
<td>23323</td>
<td>25239</td>
<td>25955</td>
<td>23600</td>
<td>3.7</td>
</tr>
<tr>
<td>Myanmar</td>
<td>54</td>
<td>73</td>
<td>75</td>
<td>60</td>
<td>63</td>
<td>2.0</td>
</tr>
<tr>
<td>Nepal</td>
<td>500</td>
<td>547</td>
<td>808</td>
<td>590</td>
<td>603</td>
<td>2.6</td>
</tr>
<tr>
<td>Pakistan</td>
<td>6383</td>
<td>8790</td>
<td>9317</td>
<td>9920</td>
<td>10538</td>
<td>5.4</td>
</tr>
<tr>
<td>Philippines</td>
<td>17</td>
<td>20</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>0.9</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>55</td>
<td>67</td>
<td>53</td>
<td>55</td>
<td>55</td>
<td>-1.3</td>
</tr>
<tr>
<td>Thailand</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Vietnam</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>24</td>
<td>25</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Twelve of the 18 major breeds of buffalo are kept primarily for milk production. The main milk breeds of India and Pakistan are the Murrah, Nili-Ravi, Surti, Mehsana, Nagpuri and Jafarabadi. Buffalo are used for milk production in, Egypt, Eastern Europe, Italy, Iran, Iraq, Turkey and Brazil.

Buffalo of the Indian Sub-continent have been grouped into the following five distinct groups:

1. Murrah Group: Comprises Murrah, Niti-Ravi and Kundi. Niti-Ravi and Kundi have their home tract in Pakistan. The former is also found in Indian Punjab along the border with Pakistan. The new breed Godavari is a cross between the local buffalo of coastal Andhra Pradesh and Murrah.

2. Gujrat Group: Surti, Jaffarabadi and Mehsana. The Mehsana has been developed from crosses between Murrah and Surti.


5. South India Group: Toda and South Kanara.

The overall production performance of buffalo in Pakistan is presented in Table 6.2

Table 6.2. Production performance of buffalo in Pakistan.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Nili-Ravi Mean</th>
<th>Range</th>
<th>Kundhi Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>39.8</td>
<td>32-58</td>
<td>35.1</td>
<td>33.4-37</td>
</tr>
<tr>
<td>Male</td>
<td>37.7</td>
<td>27-45</td>
<td>32.3</td>
<td>31-34.5</td>
</tr>
<tr>
<td>Female</td>
<td>47</td>
<td>30-54</td>
<td>52.7</td>
<td>48.57</td>
</tr>
</tbody>
</table>

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The production performance of two herds of Murrah buffalo in India is presented in Table 6.3. Age at first calving ranges from 54.6 months (Chhikara et al. 1978) to 39.9 months (Bhadula and Desai 1973) in Murrah buffalo. The first lactation performance, service period and calving intervals are presented in Tables 6.4 and 6.5, respectively.

<table>
<thead>
<tr>
<th>Age at first calving (months)</th>
<th>Weight at first calving (kg)</th>
<th>Lactation length (days)</th>
<th>Lactation yield (l)</th>
<th>Dry period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td>625</td>
<td>312</td>
<td>2070</td>
<td>160</td>
</tr>
<tr>
<td>30-54</td>
<td>544-695</td>
<td>200-450</td>
<td>1700-2700</td>
<td>95-240</td>
</tr>
<tr>
<td></td>
<td>495</td>
<td>277</td>
<td>1825</td>
<td>176</td>
</tr>
<tr>
<td></td>
<td>407-585</td>
<td>244-300</td>
<td>1580-2018</td>
<td>134-214</td>
</tr>
</tbody>
</table>

Table 6.3. Production performance of Murrah buffalo.

<table>
<thead>
<tr>
<th>Traits</th>
<th>Murrah, NDRI, Karnal 1995-96</th>
<th>Murrah CIRB, Hisar 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calving (months)</td>
<td>46.3</td>
<td>56.3</td>
</tr>
<tr>
<td>Total milk yield/ lactation (kg)</td>
<td>2303.8</td>
<td>1865.8</td>
</tr>
<tr>
<td>305 days of less milk yield (kg)</td>
<td>2101.1</td>
<td>-</td>
</tr>
<tr>
<td>Lactation length (days)</td>
<td>331</td>
<td>319</td>
</tr>
<tr>
<td>Dry period (days)</td>
<td>111</td>
<td>224</td>
</tr>
<tr>
<td>Service period (days)</td>
<td>135</td>
<td>-</td>
</tr>
<tr>
<td>Calving Interval (days)</td>
<td>420</td>
<td>554</td>
</tr>
</tbody>
</table>

The Indian diet is mainly vegetarian and people relish the hot thick creamy milk for their breakfast associated with higher fat content (Table 6.6).

Table 6.4. First lactation performance of different breeds (Mudgal and Sethi 1989).

<table>
<thead>
<tr>
<th>Breeds</th>
<th>Lactation milk yield (kg)</th>
<th>Lactation length (days)</th>
<th>Calving interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murrah</td>
<td>1635&lt;sup&gt;23&lt;/sup&gt;</td>
<td>296&lt;sup&gt;3.2&lt;/sup&gt;</td>
<td>483&lt;sup&gt;7.0&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nili-Ravi</td>
<td>1707&lt;sup&gt;30&lt;/sup&gt;</td>
<td>306&lt;sup&gt;4.4&lt;/sup&gt;</td>
<td>509&lt;sup&gt;10.1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Surti</td>
<td>1460&lt;sup&gt;28&lt;/sup&gt;</td>
<td>315&lt;sup&gt;9.0&lt;/sup&gt;</td>
<td>538&lt;sup&gt;23.0&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bhadawari</td>
<td>1165&lt;sup&gt;17&lt;/sup&gt;</td>
<td>276&lt;sup&gt;2.2&lt;/sup&gt;</td>
<td>456&lt;sup&gt;10.0&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nagpuri</td>
<td>926&lt;sup&gt;17&lt;/sup&gt;</td>
<td>295&lt;sup&gt;4.1&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>Nili Ravi (Pakistan)</td>
<td>1181&lt;sup&gt;9&lt;/sup&gt;</td>
<td>281&lt;sup&gt;0.5&lt;/sup&gt;</td>
<td>506&lt;sup&gt;4.0&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table 6.5. Average service and dry period and calving interval in different riverene buffalo.
<table>
<thead>
<tr>
<th>Breed</th>
<th>Service period (days)</th>
<th>Dry period (days)</th>
<th>Calving interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murrah</td>
<td>142±7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Murrah1</td>
<td>133±7</td>
<td>149±6</td>
<td>445±7</td>
</tr>
<tr>
<td>Murrah2</td>
<td>-</td>
<td>176±6</td>
<td>434±6</td>
</tr>
<tr>
<td>Murrah3</td>
<td>-</td>
<td>-</td>
<td>457±4</td>
</tr>
<tr>
<td>Bhadawari4</td>
<td></td>
<td>156±8</td>
<td>548±10</td>
</tr>
<tr>
<td>Nagpuri5</td>
<td>73-130</td>
<td>95-155</td>
<td>-</td>
</tr>
<tr>
<td>Nagpuri6</td>
<td>99±4</td>
<td>95-155</td>
<td>-</td>
</tr>
<tr>
<td>Dharwari7</td>
<td>133</td>
<td>148±6</td>
<td>-</td>
</tr>
<tr>
<td>Niti-Ravi8</td>
<td>211</td>
<td>198</td>
<td>530</td>
</tr>
</tbody>
</table>


They also enjoy the curd, butter milk and sweet meats prepared from buffalo milk. Buffalo milk has higher fat, protein and vitamins. Buffalo milk has less cholesterol and more tocopherol, which is a natural anti-oxidant. The peroxidase activity in buffalo milk is 2 to 4 times higher than cows milk which accounts for the higher natural preservability of buffalo milk. Buffalo milk is richer in calcium and phosphorus and lower in sodium and potassium than cow milk. It is not feasible to segregate cow and buffalo milk and collect them separately in countries where the ratio of production of buffalo milk to cow milk is high and the size of animal holding is small.

**Socio-economic impact**

In a study in Punjab (India), a predominantly buffalo area, it was noted that milk production was apparently the greatest component of economic change of the lower strata of the farming community, while income from the sale of milk constituted 25 per cent of the total farm income in Punjab. This income also corrects the negative income balances from general farming particularly for marginal and small farmers. Hence milk production is apparently the largest component of economic change in the lower section of the farming community.

**Table 6.6. Typical composition of buffalo milk and cow milk (Anon 1995).**

<table>
<thead>
<tr>
<th>Traits</th>
<th>Cow</th>
<th>Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids (%)</td>
<td>13.10</td>
<td>16.30</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>4.30</td>
<td>7.90</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.60</td>
<td>4.20</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.80</td>
<td>5.00</td>
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<tr>
<td>Tocopherol (mg/g)</td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>Cholesterol (mg/g)</td>
<td>3.14</td>
<td>0.65</td>
</tr>
<tr>
<td>Calcium (mg/100 g)</td>
<td>165.00</td>
<td>264.00</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Phosphorus (mg/100 g)</td>
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<td>268.00</td>
</tr>
<tr>
<td>Magnesium (mg/100 g)</td>
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<td>30.00</td>
</tr>
<tr>
<td>Potassium (mg/100 mg)</td>
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<td>107.00</td>
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<tr>
<td>Sodium (mg/100 g)</td>
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<td>65.00</td>
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<tr>
<td>Vitamin A (incl. Carotene) IU.</td>
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<td>33.00</td>
</tr>
<tr>
<td>Vitamin C (mg/100 g)</td>
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<td>6.70</td>
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</tbody>
</table>

Erosion of genetic resources and breeding

Crossbreeding among riverine breeds: Crossing/grading of Surti in Gujrat (India) and of local buffalo in coastal Andhra Pradesh with Murrah resulted in the evolution of Mehsana and Godavari breeds respectively. The crossbreeds involving Murrah and Surti had a lower age at first calving, shorter dry period and shorter intercalving period than both the parents.

Crossbreeding between riverine and Swamp buffalo in the Philippines, resulted in 100 per cent higher weight at one year for crossbred raised in confinement and 40 per cent under range management conditions. Milk yield in crossbreeds averaged 1300 litres compared to 500 litres in the Swamp buffalo. There was little difference in draught capacities.

Buffalo have been bred to pull loads greater than three times their body weight while also producing milk (Acharya and Bhat 1989). These loads can be pulled for two to three hours continuously and for six to eight hours a day during winter and five to six hours during summer with rest pauses in between. Working buffalo increases heart rate, respiratory activity, body temperature and plasma volume and develops a mild alkalosis. Milk production can be maintained when buffalo cows were fed and managed adequately although it is compromised under hot environmental conditions.

In the Indian sub-continent the high producing milk buffalo are brought from their breeding tracts to metropolitan cities and after completion of lactation, they are slaughtered. Similarly younger and heavier males in some South east Asian countries, because of higher demand for meat for internal consumption and export, are slaughtered, resulting in the loss of valuable germ plasm. The Haryana Government (the home tract of Murrah buffalo) in India have banned the export of Murrah buffalo from the state till they leave behind one or two calves in the home tract. Salvation of this high producing genetic material could occur by collecting their ovaries after slaughter, allowing for oocyte maturation and in vitro fertilisation and transplanting such embryos into low producing surrogate mothers.

Feeding buffalo

Buffalo digest feeds more efficiently than cattle, particularly when feeds are of poor quality and high in cellulose (Punj et al 1968; Ichhponani et al 1971 a and b; Ludri and Razdan 1980). One study revealed that digestibility of wheat straw cellulose was 24.3 per cent for cattle and 30.7 per cent for buffalo. The figures for berseem (Trifolium alexandrinum) cellulose was 34.6 per cent for cattle and 52.2 per cent for buffalo (Sharma and Mudgal 1966; Ichhponani and Sidhu 1966). In another trial, the digestion of straw fibre was 64.7 per cent in cattle and 79.8 per cent in buffalo (Sebastian et al 1970). Other nutrients reported to be more highly digested in buffalo than Zebu cattle were crude fat, calcium, phosphorus and non-protein nitrogen (NPN). Similar results have been reported from Pakistan (McDowell et al 1990).
The buffalo's success in using poor quality forages is related to:

- large rumen volume
- high rate of salivation (associated with pH control, recycling of nitrogen and sulphur)
- slower rate of passage of digestion through the reticulo-rumen,
- slow rumen motility
- higher cellulolytic activity of microbial population
- lower dry matter intake per unit body weight.

Pradhen et al (1991) reported that irrespective of the source, buffalo have a higher capacity to digest dietary crude protein and crude fibre than cattle. This has been attributed to the lower feed intake and fasting heat production (68.4 kcal/unit W0.75) than crossbred cattle (81.6 kcal/unit w0.75). Higher fibre digestion in buffalo may be due to a narrow calorie protein ratio, which is better suited to proliferation of ruminal cellulolytic microbes, than those by cattle. The additional causes for better conversion of feed in buffalo may be attributed to longer retention of feed in the digestive tract, favourable rumen conditions for NH3 utilisation, less depression of cellulose digestibility by soluble carbohydrates, higher capacity to handle the stressful environment, and a wide range of grazing preferences. In a study by Lal et al (1987), buffalo did not differ from crossbred cattle in respect to energy digestion, though these differences existed with regards to buffalo and exotic cattle. However, Agarwal et al (1990) reported higher efficiency of conversion of nutrients from feeds such as berseem, oats, maize and sorghum, to milk in crossbred cows than buffalo. This is contrary to those reported by Mudgal (1988) when straw based diet was fed to ruminant species which may be attributed to the higher activity of cellulase in buffalo (399) than cattle (300 ug sugar/mg protein) fed on a high fibre diet. However, other microbial intracellular enzyme profiles responsible for proteo-synthetic activities remain identical in cattle and buffalo on the same diet. Activities of animo-transferases and synthetases vary due to the dietary fibre and protein sources (Pradhan et al 1991).

Microbial populations in the rumen of cattle and buffalo have been compared. In general, protozoal counts were significantly higher (P<0.05) in buffalo than in cattle fed on straw and varied protein supplements. The conspicuous absence of only Diplodinium cristagalli in cattle and Qphryoslex purkynei and Epidinium ecandatum in buffalo was detected. Minimum distribution was observed in Eudiplodinium and metadinium in both species, while the occurrence of Entodinium was most predominant. Buffalo exhibited higher amounts of rumen amylolytic bacteria than cattle fed on groundnut cake as a protein supplement, but this difference vanished when another protein supplement (sesame meal) was used. Buffalo had a higher cellulolytic bacterial population in the rumen (6.86 x 10^8/ml) than in cattle (2.58 x 10^8/ml) when maintained on wheat straw and concentrate mixture. In recent studies Chhabra et al (1998) confirmed the total viable counts and the proportion of cellulolytic amylolytic and proteolytic bacteria was higher in buffalo compared to cattle. The berseem fed rumen (cattle) showed highest cellulolytic counts in cattle, whereas sorghum fed buffalo rumen recorded a higher count compared to cattle.

Since buffalo have a higher capacity to digest fibrous feeds such as straws, which are deficient in nitrogen content, various studies have shown that the NPN supplementation such as urea and biuret is utilised in buffalo in a better way than cattle. Biuret was found to be superior to urea in both the species and dry matter intake and nutrient digestibility were higher in buffalo than cattle, irrespective of NPN supplement and their level (Mudgal et al 1983). Sharma and Mudgal (1981) reported that incorporation of two and three per cent urea in the concentrate mixture of lactating zebu cattle and buffalo, fed on a wheat straw
based diet did not affect dry matter intake/kg w0.75 however, nutrient digestion was significantly higher (P<0.01) in buffalo than cattle. The level of urea did not influence the fibre digestibility and milk yield in both the species but milk fat and protein content were increased following the feeding of urea.

**Feeding strategies**

In South Asia, limited grazing, tethering and cut-and-carry feeding are more common. The principle aim of this process is to make available those nutrients which buffalo lack due to limited access to grazing. The reverse is true throughout most parts of South East Asia where buffalo derive most of their nutrient needs for maintenance and production from grazing approximately six to eight hours per day. They may also be fed with limited supplements in the evening such as cereal straws and cakes (coconut cake or groundnut cake), brans (rice and wheat) or leguminous forages (*Leucaena leucocephala*, *Gliricidia maculate* and *Manihot esculenta* Crantz) and salt.

In South Asia chronic annual feed shortages for animals and under-nutrition are common. However, there has been a significant trend towards reduced feed deficits, which is probably reflective of improved feeding systems, more efficient use of all available feeds and increasingly intensive systems of production. Further opportunities exist for reducing this feed deficit through more intensive use of non-conventional feed resources (Devendra 1988; Mudgal 1990).

By comparison, the annual availability of feed for ruminants is generally inadequate in most countries in humid South East Asia, such as Sri Lanka, Malaysia and the Philippines. In these situations, feeding strategies could be more selective, and use a variety of traditional feeds such as Guinea (*Panicum maximum*) or Napier (*Pennisetum purpureum*) grasses, agro-industrial by-products or a variety of shrubs and tree legumes.

The main concept promoted under the National Dairy Development Board's `Operation Flood' for improvement of feeding systems in India is optimal utilisation of available feed resources. Considering that the major feed resource in India is cereal straws and that the nutritive value of straw can be increased considerably through supplementation with concentrate, green fodder and some special supplementation, such as urea molasses blocks, emphasis has been placed on both cattle feed and green fodder production. Efforts have also been made to improve utilisation of straws through direct treatment of straws.

By the end of March 1990, there were 40 cattle feed plants with a total capacity of 4305 MT per day. The sale of cattle feed per litre of milk procured during 1989-90 was 205 g/l (Kurup 1990). Seventeen plants also produced bypass protein feed which formed about 18 per cent of total cattle feed production. In addition, eight urea molasses block plants have been established. These plants in 1989-90 produced and sold 407 MT of urea molasses blocks. Village demonstrations (3106) on straw treatment were also carried out. Improved fodder seeds, fodder demonstrations, and mini-kit distribution have been implemented under Operation Flood III. The programme does not distinguish between cattle and buffalo dairy enterprises.

**Special aspects of feeding of milk buffalo**

Milk of the buffalo is richer in fat and solids-not-fat, creating higher nutrient requirements. If a high producing buffalo is giving 25 kg of milk, it may require 64.8 Mcal of ME per day for milk production alone. This may be about two to three times its requirements for maintenance. To satisfy energy requirements a buffalo producing 25 kg of milk would require 16 to 17 kg of dry matter per day. As a general rule, the maximum daily intake of dry buffalo does not exceed two per cent of their live weight or 11.0 kg dry matter per 550 kg body weight. High yielding buffalo are therefore often unable to eat enough to satisfy their requirements for energy, particularly if the energy concentration of their diet is low.
It has become clear that maintenance requirements do not remain the same in dry and lactating buffalo as was assumed earlier. Recent studies have revealed that during lactation, heat production in an animal of 550 kg body weight is increased by over 2000 kilocalories per day. Therefore, for high producing buffalo to meet energy requirements, higher levels of intake are required. Also, when the level of intake increases it depresses the digestibility and ultimately metabolisable energy available to the animal because conversion into milk is less than the calculated value. Under such circumstances concentrate feeding is introduced because the high energy requirements cannot be met only by fodder.

The higher feed intake and greater transformation of digested organic matter in intermediary metabolism by lactating as opposed to non-lactating buffalo is responsible for higher maintenance energy requirements for lactating buffalo. The dairy buffalo which has higher basal metabolism during lactation will need more energy for maintenance than the dry buffalo. Thus provision of energy for maintenance in dairy cows and buffalo should be liberal (Holmes and Jones 1965; Patle and Mudgal 1977; Mudgal 1991). Moreover, in high producing animals, there is pressure to produce a greater quantity of milk. Feeding high fibre diets may add further stress in chewing, ruminating digestion. Concentrates are important in this situation.

From the studies conducted at NDDB, it has been found that when 30 per cent of requirements were given through concentrate to Surti buffalo, along with ad lib urea molasses lick and straw, milk production of 5.65 kg/day was maintained. However, the animals lost 455 g in body weight per day. On the other hand, when the concentrate level was increased to 70 per cent, Surti buffalo produced 6.27 kg milk per day and gained 246 g body weight per day (Kunju 1988). Urea molasses lick supplementation maintained milk production in both Jersey and crossbred cows without the loss of body weight at 50 per cent reduction of green fodder dry matter and ad lib feeding of rice straw. The reduction of 30 per cent concentrate or 50 per cent green fodder with sustained milk production when urea molasses lick supplemented diets of buffalo decreases, costs of production.

**Buffalo management**

Irrespective of breed, season or time of day, body temperature, respiration rate and pulse rate of buffalo in the shade is lower than that of cattle. These physiological differences often lead to buffalo being incorrectly considered to have a better heat regulatory mechanism.

**Management methods to ameliorate adverse effects of physical environment**

**Housing**

Housing needs to be very simple, because the winter is mild and the rain fall medium, with severe heat in the summer. Such a climate calls for open structures allowing plenty of air movement to keep heat stress to a minimum. A system of loose housing is best for these conditions and also saves on labour. A system for a herd of 20 cows was devised at the National Dairy Research Institute Karnal. This consists of a roofed shed 40'x15' (about 12.5 m x 4.5 m), along the 40' length on one side is a 2.5' (0.75 m) wide manger, with a water trough at one end. The remaining 12' (3.75 m) of the 15 ft (4.5 m) covered space is concreted and slopes away from the manger. There is an open paved area behind measuring 40'x35' (12.5 m x 10.75m) surrounded by a 5' (1.5m) wall with a gate (Sundaresan 1973).

**Wallowing and bathing**
Buffalo like to wallow in fresh water in herds. In hot weather, perhaps due to their thick subcutaneous fat layer and less developed sweat glands, buffalo are more comfortable while wallowing. Even sprinkling of water or showering and splashing makes buffalo comfortable. Wallowing buffalo seek out rivers, ponds and other waters in groups of five to ten animals clustered together. When sufficient water is not available particularly in the summer months, they lie in the mud to keep their body cool.

Wallowing tanks should be provided on large farms and animals in small numbers should be washed or showered once or twice a day. Various thermal ameliorative measures that have been tried include wallowing, mud plastering, sprinkling, splashing, body wetting with small quantities of water and providing cool drinking water (Pandey and Raizada 1979). Simple body wetting two to three times during the hottest part of the day was found to keep buffalo in a reasonably comfortable condition as judged by their physiological reactions (Sastry and Tripathi 1988).

**Summer sub-fertility**

Despite the evidence of some intrinsic hormonal constraints in the buffalo (Madan 1987), the problem of long intercalving periods seems to be due to environmental factors, and can be controlled by the farmer (Sastry and Tripathi 1988). Bhat et al (1983) observed that buffalo cows continue to come in heat regularly in all months, the highest incidence being after a period of wet season feeding. However, conception rates at this time are lower due to poor semen quality of buffalo bulls. Buffalo protected from high ambient temperature and direct solar radiation, and with adequate nutrition, show higher reproductive performance (Acharya and Bhat 1989). Management practices involving provision of shade and application of water to the skin surface reducing the adverse effects of a hot environment and improving estral expressivity and thus reducing seasonality of breeding, should be adopted. In addition, low levels of nutrition appeared to increase the length of the oestrus cycle.

The summer management practices desirable for improving the reproductive performance of buffalo cows includes:

**Protection against thermal stress:**

- green cover (trees, landscaping)
- proper shelter/housing
- washing/wallowing/sprinkling/splashing/showering
- cool drinking water
- cooling devices, fans, wet curtains or panels, air coolers

**Improving the nutritional status**

- feeding green fodders/silages/hay
- provision of night feeding
- grazing only if green pastures or grasslands, early morning and late afternoon
- mineral mixture supplementation.
Multiple ovulation and embryo transfer technology

Multiple ovulation and embryo transfer (MOET) in buffalo is still in the initial stages of experimentation. Whether or not embryo transfer is appropriate and worthwhile as a technological tool in buffalo reproduction improvement is difficult to appraise at the present stage of development. The initial success of Drost et al. (1983) in the United States, who pioneered application of the technology in buffalo, was soon followed with the successful birth of buffalo calves in Bulgaria and in India by Madan (1989). In view of the poor knowledge concerning the reproductive physiology and endocrinology of buffalo, embryo transfer can be instrumental in opening the way to a more accurate understanding of numerous unknown aspects of reproduction. Information concerning superovulation response, recovery rate of embryos and their quality vis-à-vis the endocrine picture of both super-ovulated and normal cyclic animals, needs to be generated for a better understanding of reproduction and development of MOET in buffalo.

So far the embryo recovery rate is only 1.16 embryos per donor with a conception rate of 14 per cent. MOET in Swamp buffalo under tropical conditions suffers from many constraints such as, detecting and regulating oestrus, setting a date for multiple ovulation and insemination, collecting embryos and finding appropriate recipients. Therefore, there is an urgent need to study the causes of the low MOET success rate in buffalo. The possibilities of single ovulation and embryo transfer (SOET) in non-superovulated buffalo needs further exploration (Singla and Madan 1990). Therefore, in developing countries where few infrastructural facilities for effective progeny testing programs under field conditions exist the MOET nucleus scheme can prove to be a useful alternative for production and evaluation of young bulls in organised/institutional herds, although this is not a smallholder technology.

FAO conferences in New Delhi, India (1988) and Varna, Bulgaria (1991) concluded that, reproduction is the major limiting factor in improving buffalo productivity. The late age at first calving, longer post-partum oestrus interval and consequently longer calving intervals, problems of detection of oestrus and poor conception rates, particularly from frozen semen are some of the problems resulting in poor reproductive performance in buffalo. There are still problems in the implementation of MOET in buffalo. A need exists for a network program with India, Pakistan, Egypt, Bulgaria, Sri Lanka, Argentina, Philippines, Thailand, China and Indonesia, with a focus on milking buffalo.

References


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Patle B.R. and Mudgal V.D. 1977. Utilization of dietary energy for maintenance, milk production and


Milking buffalo

Nili–Ravi buffalo
Feed resources and utilisation

Feeding systems in smallholder dairying are primarily based on grazing of native pastures of low productivity. The benefits of such land may range from a mere exercise ground during the major part of the year, for example in India, Pakistan, northern Sri Lanka, and Bangladesh, to a fairly good pasture, for example, in the mid country of Sri Lanka, Malaysia, Indonesia, and the Philippines. During the wet season, some weight gain and milk production is achieved which is followed by variable losses during the dry season depending on the pressure on grazing land and quality and quantity of vegetation.

In south Asian countries cattle and buffalo are generally fed on wheat, paddy, ragi and other straws and stovers. These are supplemented with small quantities of grass available from scanty grazing, or cut grass. Generally no concentrate is fed to the growing, working, pregnant and dry animals. Only lactating animals are given better feeding through supplementation of by-product concentrates such as, oil cakes, brans, and milled pulses, as farmers receives the immediate returns on their investment through saleable milk.

A survey conducted in India (Ranjhan 1997), showed the following ranges in percentages of feed components in rations varying according to agro-climatic region, season and stage of the production cycle:

Grasses and grazing 15-30%
Crop residues 66-70%
Cultivated forages 5-8%
Concentrates 2-5%

In most of the Asian countries there is a shortage of feed and fodder. While many countries import concentrates, there is little trade of roughages. The gap between supply and demand of dry matter and TDN (31%) and crude protein (58%) in India is mainly due to the low availability of good quality roughages for most of the bovine population (Ranjhan 1994).

A lot of work has been done to determine the nutrient requirements for different categories of animals, for example, Ranjhan (1994); ICAR (1994, 1997). Tables 7.1, 7.2 and 7.3 present the nutrient requirements for maintenance, pregnancy and milk production (Ranjhan 1991) in tropical cattle and buffalo, derived from work conducted in India. It should be noted that there has been little use of this information by farmers.

No precise soil, plant and animal relationship concerning mineral deficiencies has been established for the different agro-climatic regions in the tropics. Smallholder farmers sometimes feed common salt but this is not necessarily a reflection of sodium deficiency. Reports of selenium poisoning and micotoxocosis when paddy straw is fed to buffalo in Punjab in India and Pakistan, and flourosis in Andhra Pradesh and Orissa, are indicative of the need for nutrition research and sound feed management.

Up to 60 per cent of dry matter intake of dairy cows is from crop residues in many countries. These residues exhibit low voluntary intake (1.5% of body weight) as a result of the high bulk of digesta in the reticulorumen, and the slow rate of digestion. Therefore, mechanical processes associated with digestion, such as particle size, balance of nutrients and rates of microbial fermentation can increase performance on these rations. Cereal straw alone is deficient in energy, protein, minerals and vitamins.

Improvement in the feeding value of cereal straws can be achieved by physical, chemical, physico-chemical and biological pre-treatments. In physical treatment, chopping, grinding, pelleting, soaking and wetting, steaming under pressure, gamma irradiation and other such methods show variable levels of improvement in the nutritive value. In the chemical treatment, alkalis such as sodium hydroxide, acids and oxidating reagents also assist. Urea treatment of straw has been shown to benefit its digestibility by both breaking down cell walls and providing non-protein nitrogen. No methods have been widely adopted by farmers possibly because the technologies are not socially acceptable.

Farmers, perhaps wisely balance crop residues and grazing with protein rich leguminous fodders like cowpea, berseem, and lucerne, or with byproduct concentrates like brans, oil cakes, and grains, depending upon their availability and the potential milk yield of their animals.

Table 7.1. Daily nutrient requirements for maintenance, pregnancy and lactation for cattle and buffalo (Ranjhan 1991).

<table>
<thead>
<tr>
<th>Body weight (kg)</th>
<th>Dry feed (kg)</th>
<th>DCP1 (kg)</th>
<th>ME2 (Mcal)</th>
<th>TDN3 (kg)</th>
<th>Ca4 (g)</th>
<th>P5 (g)</th>
<th>Carotene (mg)</th>
<th>Vitamin A (100-IU)</th>
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<tr>
<td>Maintenance of mature cows and buffaloes6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>200</td>
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</table>

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### Dairy feeding systems

#### 5.5 Maintenance and pregnancy (last two months of gestation)

<table>
<thead>
<tr>
<th>Body weight (kg)</th>
<th>Maintenance</th>
<th>Milk production</th>
<th>Digestible crude protein</th>
<th>Metabolisable energy</th>
<th>Total digestible nutrients</th>
<th>Calcium</th>
<th>Phosphorus</th>
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<td>250</td>
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<td>3.4</td>
<td></td>
</tr>
</tbody>
</table>

1. Digestible crude protein; 2. Metabolisable energy; 3. Total digestible nutrients; 4. Calcium; 5. Phosphorus; 6. During the first and second lactation, in order to allow growth of lactating cows add about 20 and 10 per cent, respectively, of the maintenance allowance.

### Feeding dairy cattle and buffalo

Diets based on crop residues deficient in protein, energy, minerals and vitamins which restricts intake and digestibility, can be improved by providing supplementary nutrients, including:

• leguminous and non-leguminous green forages
• concentrates, and
• specific nutrient supplements in the form of mineral mixtures.

In the tropics such supplements are often in short supply and expensive. Their incorporation must be prudent and specific to the type of animal being fed.

Table 7.2. Nutrient requirements of pre-ruminant cattle and buffalo calves (Ranjhan 1972).

<table>
<thead>
<tr>
<th>Age</th>
<th>Body weight (kg)</th>
<th>Daily gain (g)</th>
<th>DCP (g)</th>
<th>TDN (kg)</th>
<th>ME (Mcal)</th>
<th>Ca (g)</th>
<th>Pg</th>
<th>Vit. A (100-IU)</th>
<th>Vit. D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to 15 days</td>
<td>25</td>
<td>200</td>
<td>80</td>
<td>0.40</td>
<td>1.5</td>
<td>2.5</td>
<td>1.5</td>
<td>1.5</td>
<td>200</td>
</tr>
<tr>
<td>15-30 days</td>
<td>30</td>
<td>300</td>
<td>90</td>
<td>0.50</td>
<td>1.7</td>
<td>3.0</td>
<td>2.0</td>
<td>1.5</td>
<td>250</td>
</tr>
<tr>
<td>31-60 days</td>
<td>40</td>
<td>300</td>
<td>125</td>
<td>0.80</td>
<td>2.4</td>
<td>3.5</td>
<td>2.5</td>
<td>1.7</td>
<td>250</td>
</tr>
<tr>
<td>60-90 days</td>
<td>50</td>
<td>350</td>
<td>150</td>
<td>1.00</td>
<td>3.6</td>
<td>4.0</td>
<td>3.8</td>
<td>2.0</td>
<td>360</td>
</tr>
</tbody>
</table>

Supplementation with green forages

Supplementing cellulosic waste with green forages is one of the most practical and traditional methods of feeding both cattle and buffalo. The animals are allowed to forage during the day on roadside grasses, community grazing grounds, tree leaves, or cut grasses. In the evening they are fed straw in corrals or stalls.

Cattle and buffalo fed with leguminous feeds, such as, berseem, cowpea, and Leucaena, when on a cellulosic waste diet in the ratio of 1:3 for maintenance and 1:1 for yearling growing calves on a dry matter basis have been shown to grow at a rate of 300-400 grams per head per day (Sen et al 1978). Any reduction in the availability of green forage will reduce the growth rate proportionally. For non-leguminous fodder, a ratio of 1:1 for maintenance and 3:1 for growth on a dry matter basis would be required.

For four to five kilograms of milk production in cattle and buffalo, leguminous forages and cellulosic waste fed in a ratio of 8:1 on a dry matter basis, provides an adequate protein and energy consumption rate of 2.5 -2.7 per cent of body weight.

Table 7.3. Daily nutrient requirement for growing dairy animals (Ranjhan 1997).

<table>
<thead>
<tr>
<th>Body weight (kg)</th>
<th>Daily gain (g)</th>
<th>Dry feed (kg)</th>
<th>DCP (kg)</th>
<th>TDN (kg)</th>
<th>ME (Mcal)</th>
<th>Ca (g)</th>
<th>P (g)</th>
<th>Carotene (mg)</th>
<th>Vit. A (100-IU)</th>
<th>Vit. D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing bulls (zebu and buffalo)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>450</td>
<td>1.2</td>
<td>200</td>
<td>0.8</td>
<td>2.9</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>500</td>
</tr>
<tr>
<td>70</td>
<td>450</td>
<td>1.7</td>
<td>220</td>
<td>1.3</td>
<td>4.7</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>500</td>
</tr>
<tr>
<td>80</td>
<td>450</td>
<td>2.0</td>
<td>240</td>
<td>1.5</td>
<td>5.3</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>550</td>
</tr>
<tr>
<td>85</td>
<td>450</td>
<td>2.1</td>
<td>250</td>
<td>1.7</td>
<td>5.8</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>550</td>
</tr>
<tr>
<td>Growing heifers (crossbred and exotic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>---------------------------------------</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>450</td>
<td>1.4</td>
<td>200</td>
<td>0.8</td>
<td>2.9</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>330</td>
</tr>
<tr>
<td>70</td>
<td>450</td>
<td>1.9</td>
<td>220</td>
<td>1.3</td>
<td>4.7</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>350</td>
</tr>
<tr>
<td>80</td>
<td>450</td>
<td>2.1</td>
<td>240</td>
<td>1.5</td>
<td>5.3</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>450</td>
<td>2.4</td>
<td>260</td>
<td>1.7</td>
<td>6.0</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>350</td>
</tr>
<tr>
<td>100</td>
<td>450</td>
<td>2.6</td>
<td>260</td>
<td>1.9</td>
<td>6.8</td>
<td>8</td>
<td>6</td>
<td>9</td>
<td>4</td>
<td>550</td>
</tr>
<tr>
<td>150</td>
<td>500</td>
<td>3.8</td>
<td>300</td>
<td>2.6</td>
<td>9.4</td>
<td>9</td>
<td>7</td>
<td>11</td>
<td>4</td>
<td>660</td>
</tr>
<tr>
<td>200</td>
<td>500</td>
<td>5.2</td>
<td>325</td>
<td>3.0</td>
<td>10.8</td>
<td>12</td>
<td>9</td>
<td>16</td>
<td>6</td>
<td>990</td>
</tr>
<tr>
<td>250</td>
<td>500</td>
<td>6.2</td>
<td>350</td>
<td>3.5</td>
<td>12.6</td>
<td>15</td>
<td>11</td>
<td>21</td>
<td>8</td>
<td>1300</td>
</tr>
<tr>
<td>300</td>
<td>450</td>
<td>7.0</td>
<td>400</td>
<td>4.0</td>
<td>14.4</td>
<td>17</td>
<td>13</td>
<td>26</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>350</td>
<td>400</td>
<td>7.2</td>
<td>420</td>
<td>4.5</td>
<td>16.2</td>
<td>19</td>
<td>14</td>
<td>32</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td>400</td>
<td>300</td>
<td>8.2</td>
<td>440</td>
<td>5.0</td>
<td>18.0</td>
<td>19</td>
<td>14</td>
<td>37</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>450</td>
<td>200</td>
<td>9.2</td>
<td>460</td>
<td>5.5</td>
<td>20.0</td>
<td>19</td>
<td>14</td>
<td>42</td>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>500</td>
<td>100</td>
<td>10.4</td>
<td>400</td>
<td>4.5</td>
<td>16.2</td>
<td>19</td>
<td>14</td>
<td>48</td>
<td>19</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Growing heifer (zebu cattle and buffalo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>150</td>
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<tr>
<td>200</td>
</tr>
<tr>
<td>250</td>
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<tr>
<td>300</td>
</tr>
<tr>
<td>350</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>
Supplementation with concentrates

Another form of use of cellulosic waste growth and milk production is the feeding of by-product concentrates. This is commonly practised in countries such as, India, Pakistan, Nepal, and the Philippines. By-product concentrates commonly available to smallholder farmers are cakes, for example, mustard, groundnut, and coconut, brans, for example rice, wheat, and maize, milling by-products, for example, broken pulses, and non-conventional concentrates, for example, palm kernel, salseed meal, cassava chips, and rubber seedmeal.

A by-product concentrate mixture prepared and fed at the rate of 1.5 kg for a 450 kg animal along with crop residue can meet the requirements for maintenance. For growth, the concentrate mixture should be fed at one per cent of body weight. For milk production, one kilogram of concentrate mixture for every three kilograms of milk in cows and two kilograms in buffalo will meet nutritional requirements.

Supplementation with specific nutrients

Dairy animals should be fed 30 to 40 grams of common salt and 30 to 50 grams of trace mineral mixture in the daily concentrate. Common salt and mineral mixture licks are often commercially available. Urea molasses mineral block licks containing deficient nutrients have proved especially useful under good management across the tropics.

Formulation of Rations

Feeding standards take into account the physiological needs for specific functions such as maintenance, milk production, growth, pregnancy, and draught. These functions require adequate amounts of energy, protein, minerals and vitamins. In normal practice the main consideration is given to energy and protein needs.

Feeding standards vary slightly between countries. Because of this the same feed is valued in a different manner and in some cases underlying assumptions of the basal diet of dairy cows in countries differ. The main feeding standards for various categories of livestock in different countries are National Research Council (NRC) recommendations of the United States and Agricultural Research Council (ARC) recommendations of the United Kingdom, which have been modified for local conditions in many countries such as for India (Sen et al 1978; Ranjhan 1991). The Indian Council for Agricultural Research (ICAR 1984) recommendations for feeding dairy animals are appropriate for India and some neighboring countries.

Before approaching the nutritional needs of any particular type of dairy animal the importance of appetite or dry matter intake (DMI) is very important. There is little benefit in offering a nutritious feed stuff if it is not consumed in sufficient quantities to meet nutritional needs. Dry matter intake varies according to the density of energy in the diet, digestibility, amount of crude fiber, the physiological nature of the feed, succulence odor, and texture. Higher ambient temperatures of the tropics reduces intake in Bos taurus cattle to a greater extent than Bos indicus and their crosses (Ranjhan and Daniel 1972).

Feeding dairy calves

The plane of nutrition of the calf plays an important role in its rate of weight gain which in turn affects its
future milk production capacity. The higher the plane of nutrition, the earlier the onset of puberty and hence lactation. The success of cattle and buffalo breeding projects in Asia depends upon successful rearing of calves to breedable age as fast as practicable, with a minimum of mortality.

**Feeding dairy calves from birth to three months**

There is no more important detail in the care and management of a dairy herd than the rearing of calves. At birth, the young calf's stomach, like the adult ruminant, is divided into four parts, although only the abomasum is functional and has an inherent capacity of about two litres at birth.

The weaning of the calves from the dams is done at birth or after four days to allow ingestion of colostrum. The colostrum should be fed within the first four hours of birth and continued over the next four days. Colostrum is high in protein which is due largely to its content of lactoglobulins which provide antibodies which can be absorbed intact up to 36 hours of age. At a later age, Y globulins are broken down by the proteolytic enzymes in the developing gastrointestinal tract of the calf. The passive transfer of the intact proteins through the mucosa of the abomasum and intestine is probably due to the absence of digestive enzymes during the first 24 hours of life and the high initial permeability of the intestinal membrane. Colostrum contains an anti-tryptic enzyme which may also help protect whey proteins from the action of proteolytic enzymes of the pancreas (Jaskowski and Jaskowski 1950). In addition to the high nutritive value of colostrum, it has a laxative effect in removing muconium. Colostrum should be fed at one-tenth of the body weight of the calf; overfeeding may be harmful. Calves that do not get colostrum and survive, produce their own autogenous antibodies to *E. coli* from about 10 days of age. Calves if left with the dams can suckle between six to seven kilograms of colostrum per day which may increase to even 10 kg by the end of the fourth day. In case the dam dies and colostrum is not available, two chicken eggs in normal dams milk may be provided to calves.

After the fourth day, the calves should be fed with the dam's milk or with milk replacers. Numerous experiments have suggested that calves must receive a minimum of 100 liters of milk in an eight week period, along with calf starter which has good quality protein and a succulent good quality fodder or hay (Dave et al 1972). The longer the period the calf has access to a plentiful supply of milk, the less need to supplement its diet with other foods. The feeding of whole milk to calves as practiced by the Indian Veterinary Research Institute is at a rate of one tenth of their body weight for the first three weeks. One fifth of the body weight in the next two weeks and one twentieth of the body weight with gradual tapering until 60 days of age (Ranjhan et al 1972). Milk schedules for different breeds are shown in Table 7.4.

Milk substitutes (replacers) can be given directly after colostrum feeding. These substitutes are based on skim milk powder which usually comprises more than 50 per cent of total dry matter. The inclusion of dry whey in milk substitutes is usually limited to less than 20 per cent of dry matter, because higher levels induce scouring in calves, caused by the high mineral content of the whey which appears to accelerate the rate of passage from the abomasum. Calves receiving reconstituted buttermilk containing about 1.3 per cent fat after the colostrum-feeding period gain weight at nearly the same rate as those given whole milk when the calves are at pasture. Skim milk, fortified with 3.5 per cent lard and homogenized, can give similar 450 gram per day growth rates in crossbred calves as achieved by whole milk (Srivastava and Ranjhan 1977).

It should be noted that, when feeding milk to calves, it is of high opportunity cost in circumstances where milk price is high. Restricted milk feeding as discussed later, would appear the most practical system for most of the tropics.

**Feeding dairy calves from three months to maturity**
The nutrient requirements for growth of calves have been given in Table 7.4. From the data presented in this table it is possible to calculate growth rations. With ordinary feeding stuffs like straws and concentrate mixture normally fed to young stock in the tropics, it is difficult to satisfy energy requirements since the straws are not as palatable, and dry matter intake seldom increases beyond two per cent of body weight.

When wheat straw constitutes the basal roughage, a rate of growth as high as 0.8 to 1.0 kg can be obtained by feeding nearly 2.5 to 3.0 kg of concentrate mixture with as little as 2.5 kg of green berseem and about 2.0 kg of wheat straw in cattle and buffalo calves over 200 kg in body weight. On a ration of this kind zebu bull calves, heifers, and crossbreeds mature at about two years of age and crossbreeds at 18 months of age. In other words, in a ration where 50 to 60 per cent of the total dry matter is substituted by concentrates the rate of growth is very much increased. Where concentrate to roughage ratio is 50:50 and 25:75, the growth of the calves can be maintained at 600 and 500 kg per day (Ranjan and Daniel 1972). However, the growth of Holstein animals was greatly depressed during hot and humid months. Where the basal roughage is wheat straw supplemented with three kilograms of green maize, the average weight gain of crossbreeds was, 421 g to 570 g and when calves were fed according to NRC requirements (Katiyar 1972). Since NRC (1971) requirements are lower than the NRC (1971) and Sen et al (1978), it is recommended that these requirements can be followed in tropical areas. An example of a growth production ration is given in Table 7.5 for the nutrient requirements for 200 kg animals.

### Table 7.4. Feeding schedule (g) for calves up to three months of age.

<table>
<thead>
<tr>
<th>Age of Calf</th>
<th>Whole milk</th>
<th>Skim milk</th>
<th>Calf starter</th>
<th>Good quality hay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haryana calves</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st 3 days</td>
<td>3000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1st week</td>
<td>- (colostrum)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4th-7th day</td>
<td>3000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2nd week</td>
<td>3250</td>
<td>-</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>3rd week</td>
<td>3500</td>
<td>-</td>
<td>100</td>
<td>350</td>
</tr>
<tr>
<td>4th week</td>
<td>3000</td>
<td>-</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>5th week</td>
<td>1500</td>
<td>1000</td>
<td>350</td>
<td>500</td>
</tr>
<tr>
<td>6th week</td>
<td>-</td>
<td>2500</td>
<td>550</td>
<td>550</td>
</tr>
<tr>
<td>7th week</td>
<td>-</td>
<td>2000</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>8th week</td>
<td>-</td>
<td>1750</td>
<td>700</td>
<td>650</td>
</tr>
<tr>
<td>9th week</td>
<td>-</td>
<td>1250</td>
<td>800</td>
<td>750</td>
</tr>
<tr>
<td>10th week</td>
<td>-</td>
<td>-</td>
<td>900</td>
<td>850</td>
</tr>
<tr>
<td>11th week</td>
<td>-</td>
<td>-</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>12th week</td>
<td>-</td>
<td>-</td>
<td>1300</td>
<td>1200</td>
</tr>
<tr>
<td>13th week</td>
<td>-</td>
<td>-</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Murrah buffalo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st 3 days</td>
<td>3000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1st week</td>
<td>- (colostrum)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4th-7th day</td>
<td>3000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2nd week</td>
<td>3250</td>
<td>-</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>3rd week</td>
<td>3500</td>
<td>-</td>
<td>100</td>
<td>350</td>
</tr>
<tr>
<td>4th week</td>
<td>3000</td>
<td>-</td>
<td>200</td>
<td>400</td>
</tr>
<tr>
<td>5th week</td>
<td>1500</td>
<td>1000</td>
<td>350</td>
<td>500</td>
</tr>
<tr>
<td>6th week</td>
<td>-</td>
<td>2500</td>
<td>550</td>
<td>550</td>
</tr>
<tr>
<td>7th week</td>
<td>-</td>
<td>2000</td>
<td>600</td>
<td>600</td>
</tr>
</tbody>
</table>
In the ration there is a shortage of about 200 g of TDN or about 1 Mcal ME which can be met if about 500 g more wheat straw is consumed by the calves. Normally it has been seen that when wheat straw forms the basal ration, calves are unable to consume the dry matter quota with the result that insufficient energy is consumed unless extra concentrate is fed which is usually uneconomical. The above ration is also deficient in about five grams of calcium and one gram of phosphorus for which about 25 g of sterilized bone meal or 50 g of complete mineral mixture can be fed. When about 25 kg of green leguminous fodder, for example, green berseem, lucerne, cowpea and Ipil-Ipil, and non-leguminous fodder, such as, ghiabati (*Ipomea pestigridis*), containing about 1.5 per cent DCP, 10 per cent TDN or 350 Kcal of ME per kg of green with about 16 per cent of dry matter is fed, it supplies about 0.37 kg DCP, 2.5 kg TDN and nine Mcal of ME.

**Table 7.5. Example of the growth production ration for a 200 kg animal.**

<table>
<thead>
<tr>
<th>Week</th>
<th>Quantity</th>
<th>DM</th>
<th>DCP</th>
<th>TDN</th>
<th>ME</th>
<th>Ca</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd week</td>
<td>3800</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>350</td>
</tr>
<tr>
<td>4th week</td>
<td>3500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>-</td>
<td>500</td>
</tr>
<tr>
<td>5th week</td>
<td>1500</td>
<td>1000</td>
<td>-</td>
<td>400</td>
<td>-</td>
<td>-</td>
<td>550</td>
</tr>
<tr>
<td>6th week</td>
<td>-</td>
<td>2500</td>
<td>-</td>
<td>600</td>
<td>-</td>
<td>-</td>
<td>600</td>
</tr>
<tr>
<td>7th week</td>
<td>-</td>
<td>2000</td>
<td>-</td>
<td>700</td>
<td>-</td>
<td>-</td>
<td>700</td>
</tr>
<tr>
<td>8th week</td>
<td>-</td>
<td>1750</td>
<td>-</td>
<td>800</td>
<td>-</td>
<td>-</td>
<td>800</td>
</tr>
<tr>
<td>9th week</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200</td>
<td>-</td>
<td>1100</td>
</tr>
<tr>
<td>10th week</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1300</td>
<td>-</td>
<td>1200</td>
</tr>
<tr>
<td>11th week</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1400</td>
<td>-</td>
<td>1400</td>
</tr>
<tr>
<td>12th week</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1700</td>
<td>-</td>
<td>1900</td>
</tr>
<tr>
<td>13th week</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Holstein, brown Swiss, crossbred

| 1st 3 days | 3000 | - | - | - |
| 1st week (colostrum) | -     | - | - | - |
| 4th-7th day | 3500 | - | - | - |
| 2nd week | 4000 | - | 100 | 300 |
| 3rd week | 3500 | - | 300 | 500 |
| 4th week | 3000 | - | 400 | 600 |
| 5th week | 1500 | 1000| 500 | 700 |
| 6th week | -    | 2500| 650 | 750 |
| 7th week | -    | 2000| 800 | 850 |
| 8th week | -    | 1750| 1000| 1000 |
| 9th week | -    | -   | 1200| 1100 |
| 10th week | -     | -   | 1300| 1200 |
| 11th week | -     | -   | 1400| 1300 |
| 12th week | -     | -   | 1500| 1500 |
| 13th week | -     | -   | 2000| 2000 |
Ration schedules used at Indian research stations for various breeds of calves over three months of age are presented in Table 7.6.

The water intake of calves is dependent on dry matter intake, ambient temperature and the proportion of salt and protein content in the diet. On a restricted milk intake, the water intake per unit of dry matter is increased during the first 60 days of life with an average of about six kilograms during winter and about 8.5 kg during the summer months per kilogram of dry matter consumed through milk, calf starter and roughage. The water intake of Holstein is markedly increased during the hot humid months and is associated with depressed feed intake.

Feeding dry calf starters and roughages

Introducing roughage and concentrates at an early age in the diets of calves will help establish rumen microflora and in the development of the rumen, resulting in an early ability to digest coarse fodders and starchy foods and to synthesise B vitamins and protein from simple nitrogenous compounds.

<table>
<thead>
<tr>
<th>Breed of animal</th>
<th>Concentrate mixture kg</th>
<th>Roughage quantity kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hariana</td>
<td>(a) 1.0-1.5 or Green oats or maize- 10 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) 0.2-1.5 or Berseem 1.5-2.5 kg +dry fodder 2 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) 1.4-2.0 Green fodder 3 kg +straw 2 kg</td>
<td></td>
</tr>
<tr>
<td>Murrah</td>
<td>(a) 1.2-1.5 or Green oats or maize or silage 10-12 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(b) 0.2-1.5 or Berseem 1.5-2.5 kg +dry fodder 2 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(c) 1.4-2.0 Green fodder 3 kg +straw 2 kg</td>
<td></td>
</tr>
<tr>
<td>Holstein</td>
<td>2.0</td>
<td>7.5-8.0 kg green oats or maize and alike fodders</td>
</tr>
<tr>
<td>Breed</td>
<td>Dry Matter (%)</td>
<td>Weight (kg)</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>2.0</td>
<td>5-10</td>
</tr>
<tr>
<td>Jersey (60 kg)</td>
<td>1.6</td>
<td>5-10</td>
</tr>
<tr>
<td>Holstein x Hariana</td>
<td>2.0</td>
<td>5-10</td>
</tr>
<tr>
<td>Brown Swiss x Hariana</td>
<td></td>
<td>5-10</td>
</tr>
<tr>
<td>Jersey x Hariana (60 kg)</td>
<td>1.6</td>
<td>5-10</td>
</tr>
</tbody>
</table>

From 4 to 6 months (90-100 kg)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dry Matter (%)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein</td>
<td>2.0</td>
<td>10-15</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>2.0</td>
<td>10-15</td>
</tr>
<tr>
<td>Jersey</td>
<td>1.8</td>
<td>10-15</td>
</tr>
<tr>
<td>Holstein x Hariana</td>
<td>2.0</td>
<td>10-15</td>
</tr>
<tr>
<td>Brown Swiss x Hariana</td>
<td></td>
<td>10-15</td>
</tr>
<tr>
<td>Jersey x Hariana</td>
<td>1.8</td>
<td>10-15</td>
</tr>
</tbody>
</table>

From 6 to 12 months

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dry Matter (%)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hariana</td>
<td>(i) 1.0 or</td>
<td>Green oats or maize- 15-20 kg</td>
</tr>
<tr>
<td></td>
<td>(ii) 1.0 or</td>
<td>15-20 kg Berseem and + dry fodder</td>
</tr>
<tr>
<td></td>
<td>(iii) 2.0</td>
<td>2.0 to 3.0 kg Wheat straw + green oats 5 kg</td>
</tr>
<tr>
<td>Murrah</td>
<td>(i) 1.25 or</td>
<td>Green oats or maize 20-25 kg</td>
</tr>
<tr>
<td></td>
<td>(ii) 1.00 or</td>
<td>25-30 kg Berseem and + dry fodder</td>
</tr>
<tr>
<td></td>
<td>(iii) 2.00</td>
<td>5 kg Straw wheat straw + green 3.0 kg</td>
</tr>
</tbody>
</table>

From 6 to 9 months (100-150 kg)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dry Matter (%)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein</td>
<td>2.5</td>
<td>Green maize, sorghum or green oats (15-20 kg)</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>2.5</td>
<td>15-20</td>
</tr>
<tr>
<td>Jersey (80-120 kg)</td>
<td>2.0</td>
<td>10-15</td>
</tr>
<tr>
<td>Holstein x Hariana</td>
<td>2.5</td>
<td>15-20</td>
</tr>
<tr>
<td>Brown Swiss x Hariana</td>
<td>2.5</td>
<td>15-20</td>
</tr>
<tr>
<td>Jersey x Hariana (80-120 kg)</td>
<td>2.0</td>
<td>15-20</td>
</tr>
</tbody>
</table>

From 1 year to age at conception (heifers)

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dry Matter (%)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hariana (130-300 kg)</td>
<td>(i) 1.5 or</td>
<td>Green oats or maize 25-30 kg</td>
</tr>
<tr>
<td></td>
<td>(ii) 1.0 or</td>
<td>Berseem + dry fodder 30-35 kg</td>
</tr>
<tr>
<td></td>
<td>(iii) 2.0</td>
<td>Straw + green 4-5 kg</td>
</tr>
<tr>
<td>Murrah (140-300 kg)</td>
<td>2.0</td>
<td>Green oats or maize 30-35 kg</td>
</tr>
</tbody>
</table>
Exotic Cross bred (200-300 kg)

| (i) 2.0 or | Green oats or maize 30-35 kg |
| (ii) 1.5  | Berseem + dry fodder 30-35 kg |

The age at which the rumen becomes anatomically and physiologically functional depends to a large extent on the diet the calf receives during pre-ruminant growth. On a limited quantity of milk the calf begins to eat alternative foods at 10 days of age, provided they are palatable. The inclusion of dry food in their diets besides increasing the size of reticulorumen also increases the weight of the tissues. Papillary development, essential to the ability to digest coarse feeds is stimulated by the end-products of rumen fermentation rather than the coarse nature of feed per se.

Birth weights of calves vary between breeds and is the most important factor determining the potential weight gain. The average birth weights of calves of Asian breeds varies from 24 to 45 kg.

The effect of limited milk feeding on the growth of Friesian, Brown Swiss, Jersey, and Hariana crossbred calves was studied by Ranjhan et al (1972). Experiments were conducted on raising. The calves irrespective of the breed were given 100 to 116 kg of whole milk and 30 to 35 kg of skim milk for 45, 60 and 90 days of age. This comprised 50 parts barley/maize, 30 parts groundnut cake, 8 parts wheat bran, 10 parts fish meal and 2 parts mineral mixture fortified with vitamins, along with green forage. From day ten the calves were fed calf starter. The calves received about 218 to 293 kcal of ME per unit body size and grew at the rate of 300 to 400 g/day during the period from birth to three months of age, depending upon the breed crosses. Other research (Razdan et al 1965; Nangia et al 1970; and Dave et al 1970). From these, general feeding schedules have been determined for feeding calves economically, (Table 7.4). Schedules have been based on age rather than body weight to facilitate implementation on-farm.

Calf starter is a balanced concentrate mixture which is fed to the calves from day 10 to supplement limited milk intake. Normally 16 per cent of digestible crude protein and 70 per cent TDN in the calf starter should give a satisfactory growth rate. The quality of protein is important during pre-ruminant growth; sesame cake and a protein source appears better than groundnut cake (Das and Ranjhan 1978). Calf starters should contain around 20 per cent of good quality protein. The following calf starter has been used since 1972 at the `All India Co-ordinated Research Project for Cattle' Centre: crushed barley or maize 50; groundnut cake 30; wheat bran 8; fish meal 10, and mineral mixture 2 parts. Also added to the 100 kg of calf starter mixture are: five to ten per cent molasses; 10 g Rovimix (Vitamins A, B2 and D3), 0.5 kg salt and 20 g of Aurofac. This mixture has given a growth rate of 350 g/day.

The constituents of the calf starters can be altered according to the availability of feeds. The barley fraction may be replaced completely by maize, and partly by rolled oats, sorghum, millet grains and rice polishings of good quality. Linseed oil meal, till cake, and soybean oil meal, may be used instead of groundnut cake. Due to the danger of toxicity from the gossypol present in cotton seed cake, it is not recommended to incorporate it into calf starters. Rice bran can be introduced in place of wheat bran provided it is free from paddy husk. Meat meal and dried skim milk are equally good for calf starters in place of fish meal, which may be replaced with groundnut cake for calves after two months of age. Molasses may improve palatability even though the calves may not be able to fully utilize the energy present in the molasses.

Feeding roughages, such as good quality hay or leguminous green fodders to calves at an early age encourages early development of rumen functions. All concentrate diets have been found to increase acid production in rumen with consequent damage to the mucosa. Dry matter intake is also reduced in the absence of roughage intake.

Good quality fodders, for example. berseem, lucerne, cowpea, maize, and stylo, can be fed to calves.
Lucerne and berseem are better types of roughages for feeding pre-ruminant calves than green maize. At three months of age calves are able to consume adequate energy and protein through starter and good quality forage, without receiving milk. However, stopping milk at 45 days can be managed without adverse effects. At this stage calves are able to obtain sufficient energy and nutrients from good quality fodder like berseem and lucerne under good management conditions. However, medium quality fodders like sorghum, oats and maize at late stages of growth, are of such a low digestibility that they limit dry matter intake (Ranjhan et al 1972).

Restricted milk feeding is practicable in smallholder tropical dairying due to the shortage of milk for the human population. With such limited milk feeding straight after birth, the calf starts nibbling dry feeds and green forages during the second week of its life. This also helps to overcome the problems of scouring and other digestive disorders of calves which otherwise complicate the rearing of calves. Management and feeding of calves has become systematic and convenient with this system, which involves less labour than that of a natural suckling system. After the rumen becomes functional, the efficiency of milk utilization decreases due to the degradation of high quality milk proteins. There is no advantage in continuing feeding of milk as greater benefit is derived from concentrate feeding. Thus this system of calf rearing is recommended for general practice both on economic grounds and in saving milk for human consumption.

Feeding dairy cows

The low average milk production of *Bos indicus* cattle and buffalo is mainly because they have been bred for draught purposes, disease resistance, tolerance to tropical climates and poor nutrition. Multipurpose animals produce 500-1000 litres of milk in one lactation with a peak of three to five kilograms per day. High producing crossbreeds produce between 2400-4000 litres of milk per day. Therefore, in feeding the dairy cow or buffalo, farmers should consider at one extreme a zebu cow weighing 250 kg, producing one to two kilograms of milk per day and consuming wheat or rice straw and a little grazing. At the other extreme could be a cross bred cow or Murrah buffalo weighing 500 kg and producing about 20 to 30 kg of milk per day, at six per cent fat in the case of buffalo, and receiving about 20 to 25 kg green fodder and 8 to 12 kg of concentrate.

The primary objectives in feeding the dairy cow or buffalo are: to allow maintenance and growth to mature body weight; to provide nutrients for the production of a calf after every 12 to 15 months, and to promote optimum quantity and quality of milk.

Calorimetric studies have revealed that during lactation, heat production in an animal of 453 kg body weight is increased by over 2000 kcal per day. For high producing animals to meet energy requirements, higher levels of intake are required which depresses digestibility. This results in the ME available to the animals for conversion into milk being less than the calculated value. Taking all these factors into consideration the NRC recommends an increase of three per cent feed for each 10 kg of milk produced above 20 kg/day.

In a normal practice on farms, the ration of a dairy cow or buffalo consists of two parts, namely: maintenance and production. The maintenance part of the ration depends upon the body weight while production is dependent upon the level and composition of the milk.

If a crossbred cow weighing 400 kg and producing 10 kg of milk per day with five per cent butter fat is fed 70 kg of berseem or green cowpea equivalent at 15 per cent dry matter the critical requirements of protein and energy are met. The digestible crude protein level is higher than the requirement and the TDN requirement for 10 kg of milk production is met with berseem. High quality feeds such as berseem
feeding can be used as a basal roughage with no concentrate needing to be fed for up to eight liters of milk production. Similarly lucerne and cowpea can be fed solely for up to eight kilograms of milk production. The cheapest feed for milk production is good quality fodders. Problems of bloat can be managed by introducing feeds gradually; it is advisable to feed about 2 to 2.5 kg of good quality hay with legumes.

For a wheat straw and concentrate mixture addition of Vitamin A and phosphorus are needed and can be supplied through a synthetic source of Vitamin A and 100 g of sterilized bone meal for phosphorus.

**Feeding dry cows**

Dry and non-pregnant cows need to be fed a maintenance ration. Requirements for a 400 kg cow are 0.25 kg DCP, 3.0 kg TDN or 10.8 Mcal of ME, 17 g calcium and 13 g phosphorus. Feeding 25 kg of green maize or good quality sorghum containing one per cent DCP, 14 per cent TDN or 60 Mcal ME, 0.6 g calcium and 0.5 g phosphorus per kg of green fodder, meets requirements, as does eight kg of green berseem or lucerne and 5.5 kg of straw. When wheat straw with 1.5 kg of balanced concentrate mixture or 800 g of groundnut cake is fed, the ration is sufficient to maintain the animal. Straw plus Leucaena leaf in a ratio of 65:35 would maintain a dry cow.

**Balanced concentrate mixture**

Balanced concentrate mixture is prepared in such a way that 3.5 to 4.0 kg of it may support 10 kg of milk production when fed over and above the maintenance ration. In most farms this mixture is fed at one third of the milk yield in the case of cattle and up to half of the milk yield in the case of buffalo, since the buffalo milk is richer in fat. For production of 10 litres of milk at four per cent fat, the cow requires about 0.5 kg DCP and 3.7 kg TDN. Therefore, if the concentrate mixture contains 15 per cent DCP and 70 per cent TDN when fed at the rate of 3.5 kg over and above the maintenance ration, it would meet the DCP requirement for 10 kg milk production although TDN would fall short which could be made up by feeding roughage. With the tropical feeds it is difficult to prepare a mixture where one kilogram of concentrate mixture may contain more than 70 to 75 per cent of TDN unless high energy feeds, such as, maize, barley and gram are used in high proportions, which increases costs to perhaps economical levels. However, minimum quantities of cereals (10 to 20 per cent) along with the by-products may contain TDN between 70 to 72 per cent. All concentrate mixtures should be fortified with one per cent salt as well as calcium and other micro elements.

Two examples of the balanced concentrate mixtures being used in various research farms in India are given below:

Groundnut cake 20 per cent
Wheat bran 45 per cent
Maize 25 per cent
Arahar chuni 10 per cent
Groundnut cake 20 per cent
wheat bran 80 per cent

Various combinations of ingredients can be compounded depending upon the cost of ingredients and cost of per unit protein and energy.

**Feeding for reproduction**

Ideally, a dairy cow should calve at yearly intervals and should have a lactation length of about 300 days.
Ideally, a dairy cow should calve at yearly intervals and should have a lactation length of about 300 days, but in practice calving intervals are often longer or lactation periods shorter. The cow therefore has a dry period of up to four to eight months. During this period the cow should build up body fat lost in early lactation which will be required to provide for the growth of the fetus and for the regeneration of mammary tissues.

In the practice known as `steaming up', dry cows are offered quantities of concentrate which increase gradually during the last six weeks of pregnancy. By the time of calving, the amount of concentrate given is about 75 per cent of the quantity the cow is expected to require in early lactation. Steaming up is claimed to increase milk production, in part by preparing the cow for high intakes of concentrates that should be fed in early lactation. During the last 60 days of pregnancy liveweight increases by about 20 to 30 kg. The response to `steaming up' probably depends on body condition at the beginning of the dry period. Restoring the reserves of the thin cow will probably have a greater effect on subsequent milk production than increasing the reserves of an already fat cow.

Normally 50 per cent of DCP and 25 per cent of TDN of the maintenance requirements are fed above the maintenance ration shown in Table 7.1. In order to cover these requirements 1.0 to 1.5 kg of additional concentrate mixture over and above the maintenance ration for a good cow and buffalo should be fed.

References


Ranjhan S.K. 1991. Chemical Composition of Indian Feeds and Feeding of Farm Animals. ICAR (Indian
Council of Agriculture Research) , New Delhi, India.


Chapter eight
Feeding dairy cows for draught
E. Zerbini and Alemu Gebre Wold

Introduction

In most crop-livestock production systems of developing countries, animals provide draught power for land cultivation and other agricultural operations. Work is another 'product' in addition to milk, meat, manure, hides and skin. In most cases farms are small and draught power is required for relatively short periods each year and farmers may not be in a position to continue maintaining draught oxen specifically for work purposes. The use of multipurpose animals such as dairy-draught cows would provide several advantages, including better utilisation of on-farm feed resources, decreased herd size and production of replacements. Nutrition and management of such animals must be adequate in order to avoid decreases in milk production and reproduction performance.

Dairy-draught cows have higher nutrient requirements than oxen particularly if they have to perform draught work during the early stages of lactation when nutrient supply has to cover the needs for work, lactation, and reproductive activity. Cows would be able to meet their requirements for work more adequately if they were able to increase their energy intake (Gemeda et al 1995; Zerbini et al 1995). Supplementary feeding may be necessary to meet their requirements for maintenance, work and other functions.
Feeding regimes of dairy-draught cows directly affect body weight and body condition. Even under conditions where adequate feed supply is not available to maintain body weight, cows could still satisfactorily perform work by drawing on body reserves. The length of time such a situation can effectively exist will depend on the previous body condition of the draught animal, the amount of work being done and its duration (Goe 1987). Energy deficits during the working season could result in body weight and body condition losses, thus, affecting production and reproduction efficiency of cows (Teleni and Hogan 1989; Teleni et al 1989; Zerbini et al 1993).

This chapter discusses nutrient metabolism, feeding requirements, feeding strategies and performance of draught cows. A number of studies reported were conducted in Ethiopia as part of a collaborative project implemented by the Ethiopian Agricultural Research Institute and the International Livestock Research Institute between 1990 and 1995.

**Energy**

**Energy metabolism and partition**

Blood glucose concentration is an important factor controlling the rate of uptake of glucose in both the liver and extrahepatic tissues such as muscle (Martin et al 1981). Besides glycogen, non-essential fatty acids are the predominant fuel in working muscle and, with \(\beta\)-hydroxybutyrate they spare glucose oxidation in muscle (Martin et al 1981). However, this sparing effect of NEFA on glucose oxidation may not be sufficient to prevent substantial utilisation of glucose in situations requiring heavy muscle work (Norris et al 1978). In working cows, glucose is not only an important energy source for the muscle but also a major substrate for lactose synthesis in the lactating/working cow and an essential energy source for reproductive activity (Young 1977; Kamiya and Daigo 1988; Butler and Smith 1989; Gaines 1989). Fatty acids are precursors of milk fat, but also seem to influence neuroendocrine activities regulating the synthesis and release of reproductive hormones (Shillo 1992). Thus, strong competition for these metabolites could occur when cows are lactating and working during the same period. Lactate and ketone bodies also play an important role in the overall energy partition strategy of dairy cows (Baird et al 1975) as well as in working animals (Updhyay and Maden 1985; Nangia et al 1978).

Plasma glucose was on average 16 per cent lower in working cows during working hours than in non-working cows, apparently indicating a substantial drain of glucose from blood to muscle (Zerbini et al 1995). However, Nangia et al (1978) did not observe any significant change of plasma glucose of buffalo in response to exercise. A significant difference in plasma glucose observed between working and non-working cows 10 hours after the end of work, is likely to be due to higher basal metabolism, even during rest as reported by Lawrence et al (1989a), thus affecting plasma glucose concentration.

The increased plasma glucose concentration observed in cows showing oestrus after a long anoestrus period (Zerbini et al 1996a), suggests a minimum blood glucose concentration requirement to trigger ovarian activity and oestrus. A greater level of nutrients intake could have induced the observed ovarian response which may have resulted from the systemic increase in blood glucose in response to lower insulin, and a concomitant change in the ratio of free fatty acids in the blood (Harrison and Randel 1986). Plasma lactate was negatively related to plasma glucose. Perhaps a greater utilisation of glucose during working hours was related to a greater concentration of lactate in muscle and therefore in blood. This might have occurred in spite of adjustments in cardiac output and metabolite concentrations occurring during work (Weber et al 1987; Zerbini et al 1992).

Plasma NEFA increased by about 150 per cent in working cows during working hours. The subsequent rapid decrease of plasma NEFA in supplemented cows during rest and feeding, corresponded to a
significant increase in glucose. Similarly, Nachtomi et al (1991) showed that increasing energy intake lowered plasma NEFA and \( \beta \)-hydroxybutyrate concentrations and raised glucose levels in dairy cows. Also, the sharp decrease of \( \beta \)-hydroxybutyrate in working cows during the first two hours of work might represent a lower synthesis of ketone bodies from NEFA which increased in plasma but were probably utilised readily as energy substrates by muscle. Beta hydroxybutyrate could also have been utilised in preference to glucose, and therefore its concentration in the plasma would have decreased over the two hours of work.

Matthewman et al (1990) reported increases in the concentrations of \( \beta \)-hydroxybutyrate and free fatty acids, and decreases in the concentrations of glucose, magnesium and inorganic phosphorus in walking cows. The response of blood metabolites to exercise was influenced by diet and some adaptation to exercise was observed over the three-week working period.

When work is imposed on the lactating cow it affects the partition of energy yielding substrates to the muscle, and free fatty acids are mobilised from fat depots. There is evidence that glucose and free fatty acids are the principal metabolic fuels for contracting muscles in working ruminants. At the same time these metabolites are also precursors of milk components and competition will occur with other functions in the lactating, working cow. However, it appears that the utilisation of glucose by skeletal muscle is insensitive to changes in physiological state, such as, pregnancy and lactation in sheep (Pethick et al 1991). This suggests that muscle has an obligatory requirement for glucose.

**Energy requirements**

Defining energy expenditure is important in the working cow because feed and body energy stores have to be channelled to different productive tasks, such as milk production and/or pregnancy and work. This is particularly important in early lactation when energy demands for milk production are high.

Data on energy expenditures of animals working under field conditions is lacking. Estimates of metabolic energy expenditure through measurements of oxygen uptake in working cows could be a useful tool in determination of nutrient partitioning and utilisation. However, such estimates under field conditions are difficult because of the technical problems involved. Recently apparatus for the measurement of oxygen consumption of working animals in the field have been developed by a number of scientists (Dijkman 1989; Lawrence et al 1989a and b; Zerbini et al 1992). Due to this new apparatus data from animals working under 'normal' conditions will be available in the near future.

Results of an investigation with crossbred cows in the Ethiopian Highlands show that dairy cows were able to work at a rate of about 500 W with draught pull equivalent to 14 per cent of their body weight. The work efficiency of cows increased from about seven per cent to 26 per cent as the workload increased to its maximum (Zerbini et al 1992). Over a period of three years, work output of dairy cows averaged more than 200 MJ per cow per year of net energy, which was well above that required by farmers for land cultivation.

An example of calculated energy expenditure of a dairy-draught cow including maintenance, lactation, work and gestation is presented in Table 8.1.

**Table 8.1. Calculated daily energy requirements of dairy cows used for draught.**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>work</td>
<td>4 hours</td>
</tr>
<tr>
<td>work rate</td>
<td>250 watts</td>
</tr>
<tr>
<td>body weight</td>
<td>450 kg</td>
</tr>
<tr>
<td>speed</td>
<td>0.5 m/sec</td>
</tr>
<tr>
<td>milk yield</td>
<td>5 kg/d</td>
</tr>
</tbody>
</table>

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap8.html#TopOfPage
Determine the annual pattern of energy demand, including that for work output, would reveal the occurrence and magnitude of the peak demands and enable appropriate feeding regimes to be defined (Preston and Leng 1987; Egan and Dixon 1993).

**Efficiency of energy utilisation**

A number of authors have reviewed the efficiency of energy utilisation by draught cattle, fed on poor quality roughage diets (Matthewman and Dijkman 1993; Pearson and Dijkman 1993). While in many instances work does not alter voluntary food intake, digestibility or efficiency of utilisation of absorbed nutrients, there are areas in which more research is needed. Ways in which work may affect the efficiency of utilisation of absorbed nutrients include the additional costs of a 10 per cent increase in resting metabolic rate on working days (Lawrence et al 1989a). The efficiency with which incoming nutrients are used to supply net energy for work is generally assumed to be the same as that for maintenance. However, more comprehensive experimental work needs to be done on this topic because work and maintenance are often the two most quantitatively important energy expenditures of draught animals and relatively small differences in efficiency of utilisation of ME would result in large differences in total energy expenditure. Finally, efficiency of utilisation of absorbed nutrients may be adversely affected in working ruminants because of extra demands for scarce glycogenic precursors.

**Nutrition**

**Feed intake**

A number of studies have reported no significant effect of work on feed intake in oxen (Lawrence, 1985; Pearson et al 1988; Soller et al 1991; Pearson and Lawrence 1992) and buffalo cows (Bamualim and Ffoulkes 1988; Bakrie and Teleni 1991). Other studies indicate an increased feed intake in working buffalo cows (Ffoulkes 1986; Ffoulkes et al 1987) and dairy cows (Gemeda et al 1995).

In a study conducted with crossbred dairy cows, Gemeda et al (1995) reported that dry matter intake was greater for working compared to non working cows, over a period of two years. Working cows fed only...
natural pasture hay (ME= 7.4 MJ/kg DM and 60 g/kg DM CP) increased roughage intake above that of non working non supplemented cows by 19.1 per cent over two years. Similarly, working supplemented cows increased hay intake above that of non working supplemented cows by 11.1 per cent. Over a period of two years, dry matter intake of working cows increased 14.9 per cent compared to non working cows. It is possible that the response of feed intake to work may have the same underlying physiological mechanism of the response to lactation since both work and lactation make extra demands on the energy supply of the cow. The increased hay dry matter intake of non-supplemented working cows is of particular importance because it indicates that cows used for work when supplements are scarce, will increase their forage intake in order to support energy expenditure for work.

A number of studies reporting small or no change in dry matter intake of draught animals included short duration trials (Lawrence 1985; Soller et al 1991; Pearson and Lawrence 1992; Zerbini et al 1996b). On the other hand, when longer periods were considered, trends changed into consistent differences (Gemeda et al 1995). This concept of adaptation to work energy expenditure is important because it reflects the capacity of cattle to adapt to energetic flows from short to long term periods. It appears that body reserves are used preferentially in the short term and then other adaptive mechanisms subside, such as increased intake of dry matter and digestion adaptations to reach a steady state. However, this situation is only possible when the diet allows intakes necessary to meet the requirements for the many functions of cows used for draught.

During the first 90 days postpartum, hay dry matter intake of non supplemented cows increased 1.6 kg/day. This was equivalent to 12 MJ ME and was associated with a body weight loss of 0.39 kg/day which equates to approximately 14.4 MJ ME. The total output was therefore 26.4 MJ ME per day. Since the total energy requirements of working cows are 111.6 MJ per day they would suffer a deficit of 25.6 MJ per day which would affect milk yield and body weight considerably. Non working cows showed a deficit of only 7.9 MJ per day (Table 8.2). Table 8.2. Effect of draught work on energy balance of draught F1 crossbred dairy cows fed natural pasture hay ad libitum (requirement calculated to support pregnancy and five litres of milk) at 90 days postpartum.

<table>
<thead>
<tr>
<th></th>
<th>Non-working</th>
<th>Working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intakes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay DM intake</td>
<td>8.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Body weight loss</td>
<td>0.32</td>
<td>0.39</td>
</tr>
<tr>
<td>Total intakes</td>
<td>71.9</td>
<td>86.0</td>
</tr>
<tr>
<td>Outputs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>45.1</td>
<td>45.1</td>
</tr>
<tr>
<td>Milk</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Gestation</td>
<td>8.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Work</td>
<td>31.8</td>
<td></td>
</tr>
<tr>
<td>Total output</td>
<td>79.8</td>
<td>111.6</td>
</tr>
<tr>
<td>Balance</td>
<td>-7.9</td>
<td>-25.6</td>
</tr>
</tbody>
</table>

Table 8.3 shows dry matter intake of supplemented and non supplemented working cows. Liveweight loss
of supplemented cows was lower and milk yield was higher compared to non supplemented working cows.

Table 8.3. *Dry matter intake, body weight loss, and milk yield of F₁ crossbred dairy cows.*

<table>
<thead>
<tr>
<th></th>
<th>90 days postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Working not</td>
</tr>
<tr>
<td></td>
<td>supplemented</td>
</tr>
<tr>
<td>Dry-matter intake, kg/d</td>
<td>9.6</td>
</tr>
<tr>
<td>Body-weight loss, kg/d</td>
<td>0.39</td>
</tr>
<tr>
<td>Milk yield, kg/d</td>
<td>3.2</td>
</tr>
<tr>
<td>Working supplemented</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>5.0</td>
</tr>
</tbody>
</table>

With a deficit of 25.6 MJ of ME, non supplemented working cows should not have been able to milk at all. However their average milk production at 90 days postpartum towards the end of the working period, was 3.2 kg per day. This could be explained by the fact that cows did not work every day but only 50 days in the 90-day period considered. Cows responded to underfeeding by a progressive adaptation until a new equilibrium between dietary supply and requirements was reached.

**Digestion**

Some authors have reported negative or no effect of work on digestion in buffalo and cattle, depending on the diet fed (Weston 1985; Bamualim et al 1987; Pearson 1990; Soller et al 1991; Pearson and Lawrence 1992), while others have shown a positive effect of work on digestibility (Ffoulkes et al 1987; Pearson and Lawrence 1992). How work could affect either rumen fermentation processes or digestion in the lower digestive tract, as well as other processes involved in intake regulation of roughage diets, is uncertain. Digestion in the rumen could be enhanced in the working animal because body temperature tends to rise (Zerbini et al 1992) and the movements of the animal would increase mixing of the rumen contents. However, Kibet and Hansen (1985) reported no significant in situ changes in digestibility of four different roughages. Average digestibility of the samples was 47 per cent when the animals were idle and 46 per cent when they walked 10 km per day.

Supplementation and work increased organic matter and NDF digestibility in dairy-draught cows. While the effect of supplements on digestibility was to be expected, since the supplement was more digestible than the hay diet, the effect of work on digestibility is more complex. The effect of work on digestibility of the non supplemented diet was apparent and significant both in the comparison between non working and working cows and within cows when they were resting and working (Zerbini et al 1996b). Another consistent effect in reported studies seems to be that buffalo fed to appetite, digest roughage better when they work. Ffoulkes (1986) and Winugroho (1988) reported average increases of 13 per cent and 6 per cent, respectively. Pearson and Lawrence (1992) on the other hand, reported both a decrease and an increase in DMD and DOMD in two different experiments with working oxen.

Digestion kinetics results reported by Zerbini et al (1996b) could explain only partially the possible mechanisms responsible for greater roughage intake and digestibility in working cows. Solid outflow rate and rumen microbial retention time were not significantly different between working and non working animals. Liquid outflow rate was reduced in working cows but it is not clear what caused this reduction. Greater Co-EDTA (a primary energy source) retention time in the rumen of working oxen was reported also by Pearson and Lawrence (1992). However, the same authors also showed an increase in fibre rumen
retention time which was not apparent in this study.

**Nitrogen balance**

The extent to which amino acids are oxidised in muscles during work in ruminant animals has not been studied. Perhaps amino acids could be used as energy yielding nutrients if the energy substrates are lacking or not in the correct proportion for protein synthesis. This is especially important in the dairy cow where glucose and amino acids are being used for milk synthesis in the mammary gland or in the gravid uterus (Teleni and Hogan 1989).

Zerbini et al (1995) carried out nitrogen balance trials in working and non working cows. Nitrogen intake and N retained were similar for working cows at work and working cows at rest. During work, supplemented cows excreted greater nitrogen in the urine mainly due to supplemented cows effect. Nitrogen balance was negative for non supplemented cows whether they were working or resting. Nitrogen retained was similar in non supplemented cows during rest and work, but was lower in supplemented cows at work than in supplemented cows at rest. The significant elevation in N excretion in the urine caused by work is in agreement with Pierson and Teleni (1991) who reported increased urinary N and higher urea entry rate in working buffalo cows. Perhaps this is associated with a reduced level of plasma glucose (Zerbini et al 1995) which induces the cows to utilise and thus remove glucose precursors arising from the process of protein turnover, thereby decreasing the possibility of N capture in protein re-synthesis (Orskov and Ryle 1990). Also, similar urine N in working non supplemented cows, whether at rest or at work, compared to greater N excretion in the urine of working supplemented cows at work compared to working supplemented cows at rest, seems to suggest that working non supplemented cows at work, increased N utilisation, perhaps through nitrogen recycling in the rumen. This could have been one factor contributing to the increased roughage digestibility especially observed in working non supplemented cows at work.

**Body condition, body weight and reproduction**

In dairy cows carbohydrate and lipid metabolism and the utilisation of body reserves in early lactation are major factors determining the use of dietary nutrients and lactation performance. If lactating cows are used for draught, the partitioning of the extra energy required for work will be in a cause-effect relationship with the physiological status of the cow.

Smith and McNamara (1990) showed that following peak lactation, animals started to regain lipid reserves. Lipids were restored to prepartum values by 240 days postpartum except in cows that were energy restricted. Dietary energy restriction also delayed the recovery of body fat during later lactation. Both, dietary restriction and genetic selection caused co-ordinated alterations in the metabolic and anatomical adaptations to lactation by adipose tissue. These results show that genotype may be important in the selection of cows that will adapt to draught work with minimal disruption to lactation. In addition, different physiological priorities between beef and dairy breeds will affect efficiency of energy use and maintenance (Solis et al 1988).

Periods of energy restriction affect reproductive performance at the hypothalamic or pituitary level, either by inhibiting secretion of the hormone GnRH and/or reducing pituitary sensitivity to GnRH. Together, these findings indicate that both exercise and the accompanying changes in body composition may influence normal reproductive function in working dairy cows (Zerbini et al 1996c). Results of Zerbini et
al (1993) indicate a decrease of the probability of conception by a factor of four in non-supplemented compared to supplemented cows and by a factor of two in working compared to non working cows. Lower glucose of working cows, only during working days, compared to a continuous lower plasma concentration in non supplemented than in supplemented cows, could account for the relatively lower effect of work compared to the effect of 'non supplementation' on reproductive performance (Zerbini et al 1993).

A clear definition of body weight and condition at the start of the work season and rate of weight loss, which are compatible with normal ovarian activity, is desirable, as well as, the effect of interaction between work and body reserve nutrients on cyclic activities in cattle and buffalo.

Another important finding is that in working cows, once pregnancy was established there was no effect of work on maintenance of pregnancy. Over a period of two years, calving intervals of working cows were on average 90 days longer than those of non working cows (Zerbini et al 1993 1995). Differences were significantly greater in the second calving interval. Diet supplementation significantly decreased days to the first oestrus and days to conception in non working and working cows (Zerbini et al 1993). When work treatment was superimposed on non supplemented treatment, the effect on reproduction was deleterious. Body condition at calving significantly affected postpartum reproductive ability of non working and working cows. This indicates that cows with greater body reserves at calving and the ability to use these reserves during the post partum period, can partly overcome the negative effect of dietary energy restrictions on oestrus onset and conception. Zerbini et al (1993) indicated that a difference of one unit of body condition score (range 1 to 9) at calving will result in an 88 per cent greater or lesser chance of conception. Similarly, Wright et al (1992) showed that calving body condition was negatively correlated with the duration of the post-partum anoestrus period. Wolfenson et al (1988) indicated that body condition at calving affected only the time taken to the start of post partum ovarian activity. However, Richards et al (1986) showed that body condition at calving was the most important factor influencing both early return to oestrus and pregnancy.

Over a period of three years conceptions in working cows were 20 per cent lower than in non working cows. On the other hand conception of non supplemented cows decreased by about 80 per cent compared to that of supplemented cows. In experiments reported by Gemeda et al (1995) cows started working two weeks after parturition and continued on a schedule of 100 working days a year up to one month before expected calving. The results showed that once conception had occurred, work did not affect maintenance of pregnancy, which suggests that pregnant cows could be used for work without affecting pregnancy if feeding is adequate.

To optimise the postpartum anoestrus period, draught dairy cows must regain weight during lactation and farmers must integrate strategically physiological events such as pregnancy and lactation with draught work requirements. An approximate 15 per cent loss in body weight represented mainly by fat was detrimental to reproductive functions of cattle and buffalo with medium body condition (Teleni et al 1989). Esualew Abate (1994) showed that greater energy intake did not reduce the incidence of ovulation without oestrus during working periods. The occurrence of ovulation without oestrus during the working period seems to decrease with time as cows adapt to draught work activity. The same authors reported that cows below medium body condition score were not able to show oestrus. However, once attaining medium body condition they started cycling and continued to cycle, indicating that a certain body energy reserve is critical to trigger ovarian activity of crossbred cows.

Body weight losses greater than 15 per cent have been reported to impair ovarian activity in female buffalo (Teleni et al 1989). Similarly, in N'Dama cows, postpartum weight losses greater than five per cent resulted in only 27.5 per cent subsequent parturitions within 21 months, compared to 50 per cent for
cows gaining weight postpartum (Agyemang et al 1991b). In another study (Gemeda et al 1995), it was found that over a period of two years, supplementary feeding reduced body weight loss of cows by 80 per cent and was associated with a 59 and 63 per cent increase in the number of conceptions and parturitions respectively, compared to a non supplemented diet. In particular, supplementation of working cows reduced body weight loss by 73 per cent and doubled the number of conceptions and parturitions compared to working non-supplemented cows. Body condition score followed a similar pattern to that of body weight change over the three-year period. This result suggests that cows in body condition score lower than three and with body weight losses of about 15 per cent or greater, would have a probability of conception not greater than 20 per cent. Body weight loss due to work (700 N, 4 h/day) was reported to be greater in heavier working buffalo in better body condition. Weight loss ranged from 0.2 to 0.50 kilograms per day (Winugroho 1988). This implies that the thinner the animal, the lower the energy required to complete the same amount of work.

Zerbini et al (1996a) reported that most non supplemented animals did not ovulate for the two year duration of the trial. During that period in which no cycling activity occurred, cows lost on average 22 per cent of their calving body weight. Conception occurred when cows had recovered 55 per cent of their liveweight loss and 106 per cent of their body condition loss. Fat increase, 100 days from the start of the repletion period, was 109 g/kg empty body fat. The corresponding value at 160 days was 178 g/kg empty body fat. The interval to repletion weight was 155 days. Cows subjected to an exceptionally long depletion period were able to resume ovarian cyclic activity and conceive in less than three months when fed twice the maintenance requirements. These results have important management implications for on-farm situations in the tropics where fluctuations of feed availability and quality occur.

Healthy cows which have been underfed to the extent that no reproductive events occurred, that is, ovulation and oestrus, for a period of more than two years, rapidly regained their reproductive ability after supplementation (Zerbini et al 1996). All cows became pregnant after a relatively short period of repletion and subsequently all calved normally. The novel feature of these results is the exceptionally long period of anoestrus associated with malnutrition. Despite this, the cows were able to resume ovarian activity and to cycle within three months of dietary repletion. The importance of reducing losses of body weight and body condition after calving in working dairy cows is well documented in the previous section. The additional energy demand due to draught work has to be considered carefully. Losses of body weight and body condition decrease the ability of cows to show oestrus and conceive. Hale (1975) suggested a 'target body mass concept' to explain the relationship between body mass and fertility and suggested that for each cow there was an optimum body-mass for conception to occur.

Milk production

Matthewman (1988) showed that walking cows expending energy at a rate of approximately 12 MJ per day experienced a reduction of milk production between seven and 14 per cent, depending on diet. Milk yield declined on walking days and recovered on non-walking days. Milk components did not seem to be affected by exercise. Similarly, Barton (1991) reported lower milk production and reproduction in draught cows in Bangladesh. On the other hand, on-farm trials in the Ethiopian highlands, indicated that the effect of work on lactation of crossbred cows used for draught was minimal when feed supply was adequate and work requirements were modest (Gryssels and Anderson 1985). Gemeda et al (1995) reported that over a period of two and three years, lactations completed by working supplemented cows were 31 and 25 per cent lower than those of non working supplemented cows, consistent with greater days in milk of working supplemented cows.

Work with inadequate feeding would not be a feasible option for a production system involving the use of lactating cows for draught. On the other hand, total milk production of working supplemented cows over...
three years was only 10 per cent lower than that of non working supplemented cows (Table 8.4). Differences could be attributed mainly to the lower number of parturitions and lactations completed among cows in this group.

**Table 8.4. Cumulative milk yield, dry matter intake and work output of F₁ crossbred cows used for draught over a period of three years.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Milk yield (kg)</th>
<th>Dry-matter intake (kg)</th>
<th>Work output (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No work</td>
<td>10</td>
<td>4502</td>
<td>10603</td>
<td></td>
</tr>
<tr>
<td>Work</td>
<td>10</td>
<td>4050</td>
<td>11841</td>
<td>705.2</td>
</tr>
<tr>
<td>Standard Error</td>
<td>328</td>
<td>375</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F Work</td>
<td>NS</td>
<td>P&lt;0.05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Differences could be attributed mainly to the lower number of parturitions and lactations completed among cows in this group.

A number of authors have reported equations to describe the relationships between dry matter and energy intake, liveweight and liveweight change of cattle (Sklan et al 1977; Coffey et al 1982; Hunter and Siebert 1986; Minson and McDonald 1987). Other equations have been developed to predict liveweight change of growing cattle and dairy cows under a number of environments (McCullough 1961; Korver et al 1985; Hand et al 1986).

Diet had a significant influence on the magnitude of the decrease in liveweight during the lactation and the time during the lactation at which minimum liveweight occurred. However, the pregnancy parameter could not be estimated accurately. Similarly, Jerez et al (1987) and Berglund and Danell (1987) indicated that change of liveweight during lactation was closely related to characteristics of the milk production curve. These studies further point out the importance of body reserves movement in the first lactation stage and the difficulties for liveweight recovery in the latter part of the lactation in inadequately fed cows (Ngwerume and Mao 1992). Prediction equations of liveweight changes including work output could also be useful to identify optimal combinations of work loads and diet within a particular stage of lactation for optimal performance of multipurpose cows.

Cows required to perform work during lactation and pregnancy have a substantially increased requirement for dietary energy (Lawrence and Zerbini 1993). If this need is not met, such cows are liable to loose excessive body-weight, which will impair milk yield and subsequent reproduction. However, some loss of liveweight could be tolerated, especially if liveweight losses during the working days could be regained during the resting days without the detriment to reproduction.

Zerbini et al (1996) indicated that cows in the supplemented diets gained 59 per cent of the liveweight lost during working days, while cows in the forage diet gained only 12 per cent. Overall, during a 90-day working period, cows lost a total of 43 kg during working days, while they gained only 28 kg during resting days between work, with a net loss of 15 kg. Since milk yield and dry matter intake were similar during working and resting days, the observed liveweight differences could be due to differences in energy output for work. However, if it is assumed that, for the supplemented diet the average loss of liveweight during working days of 1.350 kg/day was equivalent to 43.2 MJ ME and the requirement for work was 19.0 MJ ME, the difference of 24.2 MJ ME cannot be accounted for. This discrepancy resulting from differences in liveweight would indicate that in the short period (days), factors other than energy balance influence liveweight change in working cows.
balance influence liveweight change in working cows.

It would appear that factors such as, dehydration during working days and changes in gut fill, affected liveweight change in the short period (Matthewman et al 1993). These results are also supported by Zerbini et al (1996b) indicating that retention time of the liquid phase in the rumen, decreased in working cows during working days. In addition, Ortigues (1991), indicated that modifications occurring in energy balance are not totally accounted for by changes in liveweight but might be explained by differential changes in individual tissue weight and metabolism because tissues contribute to whole animal expenditure in a disproportionate manner relative to their weight. Also, there is evidence indicating that generally in dairy cows, there was a closer relation between energy balance values and milk production than with weight changes and feed intake (Berglund and Danell 1987).

Prediction of liveweight change was improved when 195 days (work + rest) was considered compared to the work period of 105 days postpartum. The coefficient for work was greater for non pregnant cows, especially in non supplemented cows. This suggests that when all cows are included, the negative effect of work on body weight change could be balanced by the positive effect of pregnancy. This is supported by the findings of Zerbini et al (1996a) where pregnant cows lost weight during working days but gained more than they lost during the resting days. The opposite occurred when cows were not pregnant. The same phenomena can be observed at 105 days postpartum.

Milk coefficients were negative and greater at 105 days compared to 195 days indicating greater influence of milk production on liveweight change during the first phase of lactation. Overall, when dry matter intake above maintenance (DMIAM) was used in the model instead of total dry matter intake (DMI), coefficients of milk and work increased. This appears logical since DMIAM is a proportion of DMI. Milk yield accounted for more than 20 per cent of the variation in liveweight change, while work output accounted for a very small portion of the total variation.

Liveweight changes occurring during working and rest days could not be predicted accurately by changes of dry matter intake above maintenance, milk yield and work output over short periods such as days or weeks. Longer periods, with direct comparisons between working and non working cows enabled better prediction, accounting for a maximum of 78 per cent of the variation.

Productivity

Productivity index (output/input)

A productivity index (PI) was calculated for dairy-draught cows taking into account the major sources of energy input and output. PI = (Milk-E + Work-E + pregnancy-E)/(Feed-E) (where E = energy). This term could be too simple because lactation and work efficiency can be influenced by the stage of lactation, milk production, time of work application during lactation, and fluctuation in body tissue gain and loss. The influence of these factors may be relatively small compared to milk production and work output but nevertheless they should not be overlooked.

In most experiments and breeding programs with dairy cows, selection has been applied to yield of milk volume. Yield rather than efficiency has been the main object of selection, as it is economically important and can be measured for large numbers of cows. Efficiency has never been the object of direct selection, mainly because it would be difficult to measure efficiency for large numbers of cows (Holmes 1988). Feed is a dominant factor in animal production because of its major effect on milk yield, reproduction and work capacity. Furthermore, the costs and the utilisation of the energy and nutrients in the ration is of great importance in the evaluation of biological efficiency of a multipurpose animal. Feed efficiency in cattle is influenced by diet and other environmental factors, genetic ability and the physiological state of the animal to utilise nutrients for milk yield and/or other functions (Korver 1988). In ruminants, the
efficiency with which food energy is used for milk production, gain and work is dominated by the efficiency of digestion of fibrous feeds in the rumen.

Feed may constitute a major part of the total cost of production in multipurpose cattle. Therefore feed efficiency should be part of multipurpose cattle breeding. Selection in dairy cattle populations has been mainly confined to milk-production traits, and genetic increases in these traits have resulted (Korver 1988). Direct selection on gross feed efficiency could be relevant for multipurpose animals where the genetic correlation between work capacity or work output and feed efficiency has not yet been established.

In the development of multipurpose cattle there is a need to identify the major traits, their relative importance and the genetic parameters. The lack of information about genetic aspects of traits which could be important for multipurpose animals is also associated with problems and costs of measuring feed intake, milk yield and work output, on an individual basis under practical conditions. Present knowledge is therefore limited and needs to be expanded with standardised research, conducted with different cattle types and in different environmental conditions. Further experimentation needs to be conducted to identify and evaluate important traits in multipurpose cattle which could allow increased efficiency of resource utilisation. These traits could then be used in crossbreeding and selection programs to produce the most appropriate cattle type to optimise utilisation and equilibrium of on-farm resources. Genetic aspects of traits related to feed utilisation and work capacity should receive particular attention.

**PI related to different functions in cattle are summarised below:**

1. Work: PI calculated for zebu and crossbred oxen ranged from 0.092 to 0.107. Output/input ratios of crossbred oxen were about 15 per cent greater than those of local oxen.
2. Milk: PI for Friesian dairy cows (from reports of Hooven et al 1968, 1972; Custodio et al 1988; Persaud et al 1991), showed an increased efficiency ranging from 0.40 for first calf heifers to 0.76 for adult cows.
3. Milk and draught: PI ranged from 0.30 to 0.35 for working and non working cows, respectively (Gemeda et al 1995).

**Herd productivity**

A herd model was used to compute herd structures and outputs annually over 10 years with three years on-station experimental data on working and non working cows (Shapiro et al 1994). The model was developed to treat the effects of the introduction of interventions such as supplementary feeds and forages, through changes in herd productivity. The value of work therefore, more than compensated for the small decline in milk production and longer productive cycle found in working cows, when supplementation took place to ensure adequate nutrition. In all the simulations, feed costs accounted for the greatest proportion of the variable costs, while the largest proportion of revenue was the value of milk produced. The greater returns to investment in supplemented working cows was therefore mainly a result of the higher value of the work output, in spite of the higher feed costs and lower milk yields. The introduction of the dual purpose crossbred cows results in a smaller average herd size, 8.4 as opposed to 12.6 livestock units.

**Practical feeding**

**Feed quality and feeding**

In most tropical environments, the period immediately prior to the cultivation season is one of food
In most tropical environments, the period immediately prior to the cultivation season is one of food scarcity, and intensification of agriculture leaves fewer and fewer opportunities for animals to graze. For both these reasons, farmers are having to rely increasingly on crop residues and conserved forages. The nutritive value of these roughages are often low and the animal may not be able to eat sufficient amounts to meet its requirements for maintenance and work. The feeds which are normally fed to working cattle and buffalo in tropical regions are fibrous roughages. The metabolisable energy content of many tropical feeds is not known with any degree of accuracy and it is often difficult to predict the voluntary intake of low quality roughages when animals are fed to appetite (Lawrence and Zerbini 1993). However, if we assume that the ME content of these feeds varies from six to eight MJ/kg DM, these feeds would satisfy the ME requirement of working cattle or buffalo expending energy at 1.7 to 2.7 times maintenance. Therefore, draught cows only consuming these feeds would be expected to lose liveweight and body condition and decrease productive performance. Diets based on crop residues or low quality hays have to be improved or supplemented, especially when working periods coincide with lactation.

In areas with available roughages containing more than nine MJ of ME/kg DM, feeding of draught animals should be adequate (Lawrence 1987). Feeds of this quality will allow animals to supply sufficient power during the working period with minimum body weight loss. However, in the case of a 400 kg working cow producing five kilograms of milk per day and working four hours per day the diet should contain at least 11 MJ ME on working days, representing an approximate energetic increase of 40 per cent above the roughage basal diet.

Two possible solutions may be recommended where crossbred cows are used for draught:

1. Production and feeding of improved forages (grasses + legumes, legumes, or other fodder) to increase digestibility and energy intake of cows to levels which would allow them to support both milk production, reproduction, and work with acceptable physiological body weight loss.

2. Production and feeding of well managed natural pasture hays and improved quality crop residues associated with concentrate feeding during early lactation, especially if cows are due to work during that period. Application of new techniques and research findings for better conservation of the natural forage during particular periods of the year needs attention.

Increased forage feed quality with urea treated rice straw or supplementation has shown increased draught capacity (Chiadet 1989; Wanapat 1989) or no change (Khibe and Bartholomew 1993) with combinations of urea and supplements used to improve a basal diet of ‘bush’ hay. Lack of change was also observed in another trial in Nepal by Pearson (1990) who fed either rice straw or rice straw + Ficus auriculata to draught oxen. A diversity of products have been used as feeds or supplements for draught animals; there is a need for site-specific research to ensure their efficient utilisation. Ffoulkes and Bamualim (1989) reviewed many of the alternative feeds used for draught animals with particular reference to those used in Indonesia. Among those listed were nine crop residues, two tree legumes and 10 concentrate feeds.

Feeding strategies

The previous section demonstrates that we are approaching a situation in which it is possible to calculate the energy requirements and changes associated with work even for multipurpose animals that may be producing milk or undergoing changes in liveweight. From these calculations it should be possible to plan the regime of animals so that food supply matches requirements throughout the year. If that strategy is not possible there are enough elements to calculate the short and long-term effects of underfeeding (Zerbini et al 1996a).

Allowing cows to lose weight and body condition during the dry season and then restore it later in the year ultimately requires more food because body mass production during re-alimentation is a less efficient
process than maintenance. However, this may be the only option where it is not possible to process or preserve large quantities of feed.

Strategies involving the provision of concentrate feeds are often difficult. Wherever possible, by-products such as oil seed cake should be used, but they may not be available when and where required and intermittent supply usually causes massive fluctuations in price. Some by-products cannot be stored for any length of time and in most places, the use of grain as a supplement for animals is hard to justify. Other sources of improved concentrate feeds for draught animals include fodder trees (Pearson 1990) and urea-treated straw (Khibe and Bartholomew 1993).

**Conclusions**

Diet was the main factor which affected body weight and body condition, and milk production of dairy cows, whether working or not. Draught work induced an increase in forage intake and digestibility. The attempt by working cows to increase intake to meet energy requirements even when fed relatively poor quality forage is important. In terms of understanding the production characteristics of working cows, there is a need to quantify the energy partition to different functions by working, lactating and breeding cows. The mechanism by which body reserves contribute to the energy expenditure of working cows is not clear. Future research priorities should include defining minimal nutrient requirements for pregnant and/or lactating working animals to allow for an optimal productive performance.

At a practical level, there are still many sources of animal feed which could be used more efficiently. Many more site-specific investigations need to be carried out with standardised experimental protocol to find the most economic combinations of feeds throughout the year and to relate food quality to animal performance. Particular attention needs to be paid to measuring voluntary food intake and feed quality since these are major determinants of total energy intake.

The relationship between work, milk production and reproduction requires additional research, with attention given to the strategic requirement of draught dairy cows to allow them to supply draught power at crucial times of the farming calendar. Work increases maintenance energy requirements of oxen or cows up to twofold and feed intake must increase to meet these requirements. Research must develop technologies for producing adequate feed on farm and to evaluate locally available sources of supplements. In particular, more work should be done on the management and nutritional requirements of the lactating draught cow and possible ways to meet its nutrient needs. This research should be conducted with a farming systems perspective in order to include those external elements which could affect adoption of cow traction technologies being developed.

Herd productivity simulated over a period of 10 years indicated that the greater returns to investment in adequately fed working dairy cows compared to non working cows or to the traditional system was mainly the result of the higher value of the work output, in spite of the higher feed costs and relatively lower off-take of milk and calves. Therefore, farmer access to suitable feeds and veterinary services should be examined. Farmers in peri-urban areas that are characterised by scarcity of land could find cow traction technology most attractive, given a profitable market for milk and calves and adequate supplies of feed.

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On-farm use of dairy cows for ploughing (F₁< Holstein × Boran), Holetta area, Ethiopian highlands.


Chapter nine
Production of forage and fodder
I.M. Nitis

Introduction
The National Academy of Sciences (1971) defines forage as aerial plant material, primarily grasses and legumes, containing more than 18 per cent crude fibre on a dry matter basis. Fodder is defined as green or cured plants such as, corn and sorghum, browse as small stems, leaves, flowers and fruits of shrubs, trees or woody vines.

The main production of most, if not all, smallholder farmers in the tropics is food crops and/or plantation crops, while forage, fodder and browse as secondary. Smallholder dairy farmers allocate land to grow grasses and ground legumes for dairy feed. In comparison, smallholder farmers involved in dryland
farming allocate land to grow fodder shrub and trees.

**Existing forage and fodder production systems**

In the smallholder farming system, the production of forage and fodder is often a sideline activity that is integrated with other areas of agricultural production. In commercially oriented livestock enterprises, forage production itself may be the main activity. In smallholder farming, input such as fertiliser is applied to increase the yield of the main crop whereas, in commercially oriented livestock production, fertiliser is applied to increase the forage yield.

**Agroforestry**

In the broadest sense, agroforestry is defined as any land use which includes both trees and agricultural production on the same piece of land (Mellink et al 1991). Agroforestry systems have existed in the tropics for centuries and have evolved to yield timber, energy, feed and human food, while contributing to the conservation of the environment. Agroforestry can be divided into many variants as indicated in Figure 9.1 (Nitis 1997). An emphasis on timber and energy production, specifies agroforestry as a silvicultural system, and when a food crop is integrated, the silvicultural system is developed into an agrisilvicultural system. When fodder shrubs and trees, forage and livestock are integrated, the silvicultural system is developed into a silvipastoral system and when the agrisilvicultural system, silvicultural system and crop residue are integrated, such integration is developed into an agrisilvipastoral system.

In the humid tropics, where the dense evergreen forest slows growth of shrub and grass layers, timber production is most common. However, in the sub-humid tropics where deciduous trees and plantation trees allow sunlight penetration for growth and production of the first and second layers, silviculture and agrisilviculture are more common. In the semi-arid tropics, where water is limiting, particularly during the dry season, agrisilviculture is less common, while silvipasture is more common. Silvipasture is most common in the arid tropics, where water and sun stresses are limiting. In the humid tropics where grasses and ground legumes are more dominant, smallholder dairy cattle and buffalo are more common, while in the dry tropics where fodder shrubs and trees dominate, smallholder dairy goats are more common.

**Forage and fodder in food crops**

Grass and ground legumes growing voluntarily under food crops are usually considered as weeds. After harvest, fields are bare or invaded with volunteer herbaceous species. Grass, ground legumes, fodder shrubs and trees may be grown on the bunds, on the sloping land between terraces and along field boundaries. All of these constitute feed for dairy cattle.

In the wetland farming areas of Bali, Indonesia, yield of grass and ground legumes varies in dry matter (DM) from 0.48 to 1.89 tons per hectare during the wet season and 0.86 to 1.24 t/ha during the dry season (Nitis et al 1980). In the dryland farming area, yields of grass and ground legume vary in DM from 0.91 to 1.85 t/ha and from 0.89 to 1.38 t/ha during the wet and dry seasons. Such grasses and ground legumes consisted of 23 to 31 species dominated by the genera *Axonopus*, *Chrysopogon*, *Paspalum*, *Pennisetum*, and *Trifolium*. 

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The lopping yield of fodder shrubs and trees in the wetland farming areas of Bali ranged in DM from 2.19 to 3.8 t/ha and 2.23 to 6.94 t/ha during the wet and dry seasons, respectively; in the dryland farming area the fodder yield ranged in DM from 1.65 to 6.32 t/yr and from 2.55 to 8.35 t/yr during the wet and dry seasons, respectively (Nitis et al 1980). Higher dry season yields result from more frequent lopping, when grasses and ground legumes are in a short supply. In the wetland farming area, about 26 fodder shrubs and 31 fodder trees grow along the bund of a one hectare field; in the dryland farming area, about 104 fodder shrubs and 304 fodder trees grow around the bund of a one hectare field. Of the 43 and 55 varieties of fodder shrubs and trees lopped during the wet and dry seasons, respectively, the most common shrubs are Gliricidia, Leucaena, Caliandra and Acacia villosa; the most common trees are Artocarpus, Lannea, Hibiscus, Ficus and Azadirachta.

**Forage under plantation crops**

Grasses and ground legumes growing voluntarily under plantation crops are removed as weeds. Shrub and tree legumes, on the other hand, may be purposefully grown as climbers for vanilla, as shade for coffee, as green manure for coconut, or along the boundaries of plantations.

Yield of grass and ground legumes under plantation crops range in DM from 0.81 to 1.60 t/ha and from 0.92 to 1.25 t/ha during the wet and dry seasons, respectively (Nitis et al 1980). The 26 to 31 species of
grasses are dominated by the genera of *Schema*, *Paspalum*, and *Pennisetum*. Lopping yields of fodder shrubs and trees under plantation crops range in DM from 2.98 to 5.73 t/ha and from 2.79 to 6.24 t/ha during the wet and dry seasons, respectively. *Leucaena* and *Gliricidia* are the dominant shrubs and *Erythrina*, *Hibiscus* and *Lannea* the dominant trees in Indonesia.

### Forage and fodder under forest

Forests can be classified into evergreen and deciduous forests (Cheva-Isarakul 1986). Because light intensity becomes the first-limiting factor, forage growing under forests should be shade-tolerant. In the mixed deciduous forest in Thailand for example, the main undergrowth consists of *Bambusa*, *Thysrosfachs*, *Imperata*, *Eulalia*, *Casearia*, *Euphorbia*, *Phoerire*, *Acroceras*, *Morinda*, *Aacacia*, *Poecia*, *Leersia* and *Eupatorium* (Cheva-Isarakul 1986). In the abandoned swidden, the grass and shrubs commonly found are *Eulalia*, *Leersia*, *Sida*, *Solanum Thysonolaena*, *Acroceras*, *Agratam*, *Bambusa* and *Thysrosfachs*. Yield of the forage DM under the mixed deciduous forest in Thailand is about 2.4 t/ha during the rainy season (Cheva-Isarakul 1996). During the hot, dry season, however, no green forage is left, because the ground under the forest is covered with dried leaves, sprouts, shoots, pods, and fruits of the forest trees.

### Forage and fodder on fallow land

In the sloping dryland farming area, farmers usually crop the land continuously for three years and then leave it fallow for four to six years. During this fallowing period, the natural grass and broad-leafed species voluntarily invade fields. Fallow land is used to tether the cattle and goats for intense grazing such that no forage is left during the dry season. In the dryland farming area in Bali, the average yields of DM for natural pasture in the fallow land is 0.88 t/ha during the four month wet season and 0.44 t/ha during the eight month dry season (Nitis et al 1989). Such natural pasture is dominated by *Sporobulus*, *Polytrias*, *Heteropogon*, *Themeda* and *Chloris*.

### Forage and fodder in natural grassland

Grassland develops as a result of shifting cultivation and the degradation of climax forest and is maintained by uncontrolled overgrazing and dry season burning. Large areas of natural grassland are found in Indonesia, particularly in, Sumatra, Kalimantan, Sulawesi, Nusa Tenggara, and Irian Jaya (Ivory and Siregar 1984). The natural pasture consists of many grasses and ground legumes, with the most common genera being *Imperata*, *Paspalum*, *Chloris*, *Eleusine*, *Themeda*, *Heteropogon*, *Polytrias*, and *Desmodium*. Yields of DM vary from 0.66 to 1.24 t/ha during the wet season to zero during the dry season because of overgrazing and burning (Nitis et al 1989). *Imperata cylindrica* occupied 16 million hectares in Indonesia, and the area is increasing at 0.15 million hectares annually. *Imperata cylindrica* is an important forage for animal production in Southeast Asia at its early stages of growth (Falvey 1981).

### Forage and fodder on critical land

Critical land is no longer capable of playing a role in production, hydrology, or ecology functions as a result of overgrazing, continuous cultivation, bushfires, and deforestation of marginal land (Department Pertanian R. I. 1988). Such forage is dominated by annuals, which grow fast and produce plenty of seeds during the wet season. Perennials consist of shrubs and trees, which grow during the wet season and mid dry season.

### Yield of forage and fodder

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Potential yield and lopping yield

Potential yield is the foliage available from defoliation (Nitis 1992). This is practised in the plantation crops where fodder shrubs and trees are used as climbers and have to be lopped completely to prevent shading of vanilla or pepper. Lopping yield is the amount of foliage available through strategic and systematic defoliation as practised in plantation and food crops, where fodder shrubs and trees are used as shade and fences. The lowest branch can be lopped first, then the upper branches until two thirds of the canopy has been cut, by which time, new bud premordia have developed on the lower branches.

Sustainable yield

The aim of improved forage and fodder production is year round production. Species which produce well during the wet season can be complemented by those that produce during the dry season.

Reynolds (1995) suggests the following methods of overcoming the problems of seasonal variation in forage and fodder production:

- Reduce production seasonally by growing a range of species and by judicious use of fertiliser to extend the growing season.
  - Use a grass-legume mixture to prolong higher quality of feed in the dry season. Because legumes may be deeper rooted and of higher nutritive value, they could supply better forage.
  - Use browse as shrub and tree fodder particularly during the dry season.
  - Use fast-growing grasses, such as *Pennisetum purpureum* and *Panicum maximum* under intensive management by using irrigation and fertiliser to increase yield to genetic potential.

Predicting potential yield

To feed the livestock to optimal production levels, smallholder farmers should know the amount of feed available during the wet and dry seasons. Various methods to measure the quantity of grassland vegetation have been described (’t Mannetje 1978). However, smallholder farmers do not require accurate measurement but a good estimate of the amount of forage and fodder available on their own farms.

Grass and ground legume

The simplest method to estimate grass and ground legume yield is by using a quadrate. Farmers can make a quadrate from wood or galvanised iron rods, one meter square. The vegetation inside the quadrate is cut. Sampling is repeated in the centre, diagonal crossing, and edge the field and yield per hectare can be estimated by using an equation: \( Y = R \times 10,000 \), where \( Y \) is fresh weight yield in one hectare and \( R \) is yield in one square meter.

Fodder shrub and fodder tree

The potential fodder yield of shrubs and trees can be estimated by measuring stem diameter, and entering the values in a formulated equation. Petmak (1983) showed that leaf yield of a tree can be predicted by using the allometric equation of log \( W = 2.24 \log DT -1.50 \), where \( W \) = leaf yield in kilograms of dry weight and DT is trunk diameter (cm) at 130 cm height. For the leaf yield of a shrub the allometric equation is log \( W = 2.62 \log DS -2.46 \), where DS is the stem diameter (cm) at 30 cm height. With sowing
machine tape, farmers can measure the circumference of the trunk or stem and calculate the diameter by using the equation: \( D = 0.636 \times C \); where \( D \) is the diameter and \( C \) is the circumference.

Khan and Petmak (1989) showed that in predicting the leaf yield of *Leucaena* grown on wet land, the age of the plant, height and site of the diameter measurement should be taken into account. For instance, when the *Leucaena* was four years old, collar diameter (CD) was a better parameter, with leaf yield equaling: \( Y = 1 + 1.15 \times (1 + CD)^{1.16} \). However, when *Leucaena* was seven and a half years old, the diameter at breast height (DBH) was a better parameter, with leaf yield equal to: \( Y = 1 + 0.089 \times (1 + DBH)^{1.49} \). Height alone was not a good indicator.

For shrubs with many primary branches, the stem diameter is the total diameter of the stem and all the primary branches. Muliani (1992) showed that for *Gliricidia sepium* with its many primary branches, the equation \( Y = 0.28 + 3.62 \times X \) predicts leaf yield (\( Y \)) in grams of DW per tree where \( X \) is the sum of the diameter of stem and primary branches squared.

### Means and ways of increasing yield

#### Fertiliser

As prices of artificial fertiliser increase, its efficient use is essential. Some improved grasses such as *Brachiaria decumbens*, *Digitaria decumbens* and *Pennisetum purpureum* respond well to nitrogen fertiliser when grown in pure stands (Skerman and Riveros 1990). In Puerto Rico, *Pennisetum purpureum* fertilised with 897 kg N/ha produced 84,800 kg DM/ha/yr (Vicente-Chandler et al 1950). In some grass species the response to N requires the addition of other minerals. *Pennisetum clandestinum* responds strongly to high levels of N and P (McWilliam et al 1970), *Cenchrus ciliaris* responds highly to P, and N in the presence of P (Humphreys 1959) and *Setaria sphacelata* cv Kazungula has been found to be competitive for P, N and K and can establish itself in soils where deficiencies occur using other grass species (Mears 1969).

Native grasses do not respond adequately to artificial fertilisers. An experiment conducted in Puerto Rico showed that native grass dominated by *Axonopus* fertilised with lime + 224 kg P\(_2\)O\(_5\) + 244 kg K\(_2\)O produced 7,028 kg dry forage per hectare, while the mixture of *Melinis minutiflora* (molasses grass) and *Pueraria phaseoloides* (tropical kutzu) without fertiliser, produced 13,877 kg dry forage per hectare (Skerman and Riveros 1990). The presence of N from the root nodule of kutzu is high enough to stimulate the vegetative growth of the molasses grass.

Even though N is supplied by the legume in grass-legume mixtures, other artificial fertilisers should be applied to increase the forage yield. Yield of mixture of molasses grass and tropical kutzu fertilised with lime + 224 kg P\(_2\)O\(_5\) and lime + 224 kg P\(_2\)O\(_5\) + 224 kg K\(_2\)O was 39 per cent and 46 per cent higher respectively, than those without fertiliser application (Skerman and Riveros 1990).

For smallholders, barnyard manure, at their disposal on the farm, when applied regularly at the right time, can not only increase the forage yield, but can also increase the soil organic matter and improve the soil structure for future production benefit. When applied at the right concentration, the 15 t/ha of organic fertiliser can increase dry matter yield of *Pennisetum purpureum* 121 per cent more than the NPK fertiliser applied at 300 kg N, 80 kg P and 50 kg K/ha (Halim 1993).

Fertiliser is not usually added to smallholder fodder shrubs and trees. Indirect fertiliser is received when the fodder shrubs and trees are integrated with food and plantation crops. Fodder shrubs such as *Gliricidia* and *Leucaena* grown in alley cropping will receive fertiliser, and fodder shrubs grown for climbers will
receive fertiliser when the vanilla and pepper are fertilised. Fodder trees such as *Erythrina* and *Albizia* grown as shade will receive fertiliser when estate crops such as coffee and clove are fertilised.

**Grass-legume mixture**

According to Skerman and Riveros (1990) short, leafy grasses reduce competition for light and bunch grasses are preferable to strongly stoloniferous or rhizomatous grasses. Where the dry season is severe and long the most drought tolerant grasses such as *Cenchrus ciliaris* cv Guyndah may not be the most desirable, since they compete more strongly with legumes for limited water. A less competitive grass such as *Panicum maximum* cv Trichoglume that tolerates the dry season well and recovers quickly in the following rainy season may be more desirable.

Soil type also plays a role, as in northern Thailand where *Brachiaria mutica* is less vigorous on lateritic soil, while *Centrosema pubescens* grow quite well, so that a satisfactory grass-legume balance is maintained (Skerman and Riveros 1990). In Hawaii, when *Desmodium intortum* was adequately fertilised with P, K, Mo and Zn it was able to compete successfully with *Pennisetum clandestinum* and *Digitaria decumbens*.

Some rhizomatous and stoloniferous grasses such as *Brachiaria decumbens*, *Brachiaria mutica* and *Digitaria decumbens* are incompatible with legumes, mainly because of competition for light and nutrients, particularly N and P (Skerman et al 1988). The legumes usually persist for one to two years, the N fixed by legumes encourages grass growth and the legume is eventually suppressed, leading to grass dominant pasture. *Neonotonia wightii* is the only legume that could survive for more than three years when mixed with *Digitaria decumbens*.

Grass-legume mixtures are best kept as simple as possible, since management is complex. Evans et al (1992) suggested that good management of mixed pasture should aim to maintain at least a 20 to 30 per cent legume component. The recommendation that is frequently made for areas where there is sufficient rainfall or irrigation is to use one quarter of the farm area for N-fertilised grass and the remainder for a grass-legume mixture (Skerman and Riveros 1990).

**Association**

In the Sahel dry tropic of west Africa, productivity of *Pennisetum* grass under *Acacia* trees is around two times higher, the grass dries out three to six weeks later and the photosynthetic efficiency four times higher than in the open (Bille 1978). In semi-arid Queensland, Australia, the yield of *Cenchrus* grass under mature *Eucalyptus* trees is higher than that from the inter tree area (Christie 1975). In dryland farming areas in Bali, Indonesia, fodder yields of *Gliricidia* in association with *Cenchrus* grass, are around six per cent higher, while CP content was 11 per cent lower than *Gliricidia* cultivated in association with *Panicum* grass (Lana et al 1992). Fodder yield, CP, NDF and ADF contents of *Gliricidia* in association with Graham stylo, have been found to be nine, three, six and 13 per cent higher, respectively, than the *Gliricidia* in association with Verano stylo. Furthermore, *Gliricidia* in association with *Ficus* trees have fodder yield, NDF and ADF contents 14, 5.0 and 11 per cent higher respectively, than the *Gliricidia* in association with *Lannea* trees. During the wet season, *Gliricidia* yield is highest in association with *Cenchrus* and during the dry season yield is highest when in association with *Hibiscus*. In the case of fodder trees, yield of *Ficus* is highest in association with Verano stylo; while yield of *Lannea* was highest when in association with *Gliricidia* during the dry season (Nitis et al 1989).

Associations with food crops have shown increased leaf yield of *Acacia*, *Peltapharum*, *Leucaena* and *Eucalyptus* by 257, 255, 250 and 196 per cent, respectively (Petmak 1983).
Shrub and tree spacing

*Gliricidia sepium* planted as fencing (0.1 m spacing), alley cropping (0.5 m spacing) and as guardrows (1.0 m spacing) and harvested four times a year, produced 0.20, 1.48 and 1.94 kilograms of DM per tree per year, respectively (Nitis et al 1991a). However, when the yield was expressed per 100 m row, the DM yield became 207, 297 and 195, respectively. *Leucaena* planted at higher density (shrub per square meter) produced better yield (per hectare per year) than *Leucaena* planted at lower density (Horne et al 1985).

Weed control

Annual weeds grow prolifically during the wet season and produce plenty of seeds before drying-off during the dry season. Perennial weeds persist for many years because of their stoloniferous and rhizomatous vegetative growths. Blady grass (*Imperata cylindrica*) is one of the persistent perennial weeds which occupied about 500 million hectares worldwide, about 200 million hectares of which are in Southeast Asia (Martoatmodjo 1976).

Uncontrolled weeds reduce the forage and fodder productions. Some weed control methods are as follows:

Management

Weed problems can be minimised with good seedbed preparation so that the aggressive grass species can compete with the weeds. Reynolds (1978) showed that the aggressive *Brachiaria brizantha* could suppress the weed component to 20 per cent after six months. Wu Renun and Xu Xuejun (1993) showed that *Brachiaria decumbens* can suppress the noxious weed *Chromolaena odorata* such that within three years there was no weed present in the pasture. For the established pasture, optimal grazing height and correct stocking rate is the best insurance against weed invasion. With correct planting and cutting management *Gliricidia sepium* has been used to suppress blade grass weed in Indonesia. *Gliricidia* stake of 1.25 m length with 2.5 - 3.0 cm diameter is planted at 25 cm depth with two square meters spacing in the blady grass field at the end of the dry season. After being established for one year the stake is cut at 30 cm height, so that the sprout of *Gliricidia* shoots will shade, suppress and eventually kill the blady grass.

Mechanical

Rhizomatous and stoloniferous weeds should be up-rooted by chisel during the land preparation. The land should be ploughed and then rested for two to three weeks so that the seeds of the annual weeds can germinate and be killed by re-ploughing the emerging weed seeds. Slashing can prevent weeds from flowering and seeding.

Biological

Beetles and insects have been used to control certain weed species. Beetles (*Uroplata giradi*) which feed on the leaves of the weed *Lantana camara*, eventually cause a decline (Reynolds 1978). In Papua New Guinea, the weed *Mimosa invisa* was controlled very successfully by the insect *Heterophylla spinulosa* (SPC 1994), and in Sri Lanka, a leaf eating insect (*Ammalo insulata*) initially controlled the troublesome weed *Chromolaena odorata*, but did not persist.

Chemical
Reynolds (1995) stated that the effect of herbicide on weed species is influenced by species characteristics, the amount of herbicide applied, the time of application in relation to age and stage of growth of the weed and the environmental conditions at and after the time of application. The absence of rain for at least three hours after application for foliar applied herbicides is especially important. Herbicides are classified according to whether they kill all plant materials or only specific species. Furthermore, the foliar applied herbicides may be divided into those that kill on contact or those that are translocated through plant tissue into the root system.

Irrigation

In smallholder wetland farming areas, irrigation water is mainly used for food crops. Unless forage and fodder are grown instead of food crops, water-loving grasses such as *Pennisetum purpureum* can be grown on bunds, swamp areas, riverbanks, and upland areas.

Grasses usually respond to irrigation water better than the grass-legume mixture or legume alone. In Western Australia, Robert and Carbon (1969) showed that irrigated *Pennisetum purpureum* yielded 41,931 kg DM/ha; while irrigated *Chloris gayana, Brachiaria mutica, Digitaria decumbens, Setaria sphacelata* and *Paspalum dilatatum* each yielded over 20,000 kg DM/ha. On the other hand, the highest yielding grass-legume mixture of 16,226 kg DM/ha were with grass in association with siratro, lotononis and glycine in that order. In the Burdekin area of north Queensland, Allen and Cowdry (1961) showed that the highest yield of irrigated grass-legume mixture of *Brachiaria mutica-Centrosema, Panicum maximum-Stylosantes, Chloris gayana-Stylosanthes* and *Panicum maximum-Centrosema* was 2.5, 1.9, 1.7, 1.6 and 1.4 tons of dry weight per ha, respectively.

The growth habit of most tropical forage legumes makes water movement through the sward difficult to manage and where spray irrigation is applied, shifting the pipes through the mass is difficult to manage and tiresome (Skerman et al 1988).

Land preparation and plant species

Land preparation

For smallholder farming, land clearing, soil preparation, planting and harvesting are usually done manually, unless farmers join together to use machinery.

Land

The first step in land preparation is clearing the land of unwanted weeds, shrubs and trees. Some fodder shrubs and trees in strategic locations should be left, for fodder supply, soil protection, shade, wind breaks, fencing material, firewood, as a sanctuary for wildlife and for aesthetics.

Millable trees are harvested first, followed by trees for fuel wood and shrubs for firewood or charcoal, for sale to offset some of the cost of forage establishment. Burning is done one to two weeks before the rainy season is expected so that the valuable ash mulch is not blown away before the pasture seed is planted. Care should be taken, so that the fire does not spread to the neighbouring fields.

Soil preparation

For the forest land just cleared, soil should be ploughed to aerate the topsoil and to mix the ash and the
topsoil. For native pasture in the fallow land, soil should be ploughed at least twice; first ploughing to break the soil, second ploughing to aerate the soil and third ploughing to kill the emerging weeds. On the sloping land the furrow made should be parallel to the terrace to prevent soil erosion and washing down the seeds and seedlings. At least 0.6 ha of improved forage and fodder per head of cattle should be sown.

**Choice of plant species**

**Tolerance to salinity and/or alkalinity**

Salinity is common both in dryland and tidal areas. According to Skerman and Riveros (1990) salt-affected soil may be classified into saline soils which contain a concentration of soluble salts high enough to depress plant growth and alkaline/sodic soils which contain enough exchangeable sodium to affect plant growth adversely. The lower limit for a saline soil has been defined as 4.0 mmhos/cm and for a sodic soil as 15 per cent exchangeable sodium (Bernstein 1962). Maas and Hoffman (1977) classified suitability of irrigation water for crops under the following system: 0-8 is suitable for salt-sensitive crops, 8-16 is suited to moderately sensitive crops, 16-24 is suited to moderately tolerant crops, 24-32 is suited to tolerant crops and over 32 is unsuitable for any crop.

Salinity initially affects germination and once germination has succeeded, subsequent growth may not be seriously affected. Skerman and Riveros (1990) described the mechanism underlying the salt-tolerant plant species as follows: ‘If certain salt-tolerant plants are established they will gradually bring about the necessary base exchange as a result of the carbon dioxide liberated from the roots. This forms carbonic acid and if calcium is present the calcium salt is formed and base exchange takes place with the sodium clay’. Ryan et al. (1975) showed germination of a range grasses to be influenced not only by salt concentration but also by the nature of the ions in the salt solution.

An ecological survey of tropical and subtropical plants, indicated that the *Chorideae*, *Sporobaleae* and *Aeluropodeae* tribes are tolerant of salinity (Lipschitz et al 1974). Salt glands appearing in longitudinal rows parallel to the vein were observed on both leaf surfaces of species belonging to genera of these three tribes.

**Tolerance to shading**

In agroforestry systems shade-tolerant forage exists under the young timber forests and plantation crops such as coconut, oil palm, kapok, rubber, vanilla and cloves. Dense foliage canopies of the plantation intercept light, slow air movement, lower air and soil temperatures and increase soil moisture and relative humidity.

Morphologically the shade tolerant plant has longer and thinner leaves (Ludlow et al 1974; Wilson 1991) resulting in lower rates of respiration, lower root/shoot ratios and greater leaf area/leaf weight ratios which improve competitive ability by increasing interception of light and reducing respiratory load (Trendbath 1976).


**Resistance to drought**
Droughts induce different morphological, phenological, anatomical and physiological modifications in trees and understorey crops in agroforestry systems (Chaves and Pereira 1992). In acclimatising, the most important mechanism is partial closure of the stomata, slow down of foliage growth, and shifts in carbon allocation. During dry periods when stomata are closed, high light intensity and tissue temperature and water deficit reduces photosynthetic capacity. The same may occur in shade adapted understorey plants if suddenly exposed to high temperature and incident irradiance under drought-deciduous tree canopies.

The survival of plants under drought conditions is partly due to maintenance of photosynthetic capacity in younger leaves which are less affected by drought (Chaves and Pereira 1992).

Drought-tolerant grasses exist in the genuses of *Bothriochloa, Cenchrus, Chloris, Cynodon, Dichanthium, Digitaria, Eragrostis, Panicum, Paspalum,* and *Setaria.* Drought-tolerant legumes include *Leucaena leucocephala* and *Centrosema pubescens.*

**Tolerance to waterlogging**

Permanently waterlogged soil, such as found on riverbanks lake sides, and swampy areas, and temporarily waterlogged soil such as found on low lying areas have the potential to grow grass, ground legumes, fodder shrubs and fodder trees.

Plants tolerant to permanent waterlogging, may differ from those tolerant to temporary waterlogging. Cultivars have also been developed to suit the degree of tolerance to waterlogging. Whiteman et al (1981) showed that the order of waterlogging tolerance decreased from *M. lathyroides, S. guianensis* cv Schofield, *M. atropurpureum* cv Siratro to *C. pubescens* cv Common. Gilbert et al (1992) reported that *M. lathyroides* cv Murray, *M. atropurpureum* cv Siratro, *C. schiedianum* cv Belalto, *S. guianensis* cv Cook and *S. hamata* CPI 33205 were tolerant. In the Philippines, *Centrosema pubescens* survives in stagnant water for at least two months (Farinas 1996). Evans et al (1990) reported that *Desmodium intortum* is also well adapted to poorly drained soils and *Centrosema pascuorum* cv Calvacalde withstands prolonged waterlogging and seasonal flooding.

Some grasses tolerant of permanent logging are: *Acroceras macrum, Brachiaria mutica, Echinochloa crus-galli, Echinochloa pyramidalis, Hymenachne acutigluma, Hymenachne amplexicaulis, Leersia hexandra,* and *Vossia cuspidata.* *Panicum, Phragmites, Saccharum* species suit river banks while many grasses appear to tolerate seasonal waterlogging.

**Tolerance to acid/high aluminium soil**

Soils with pH levels below 4.5 are often associated with high aluminium levels. Experiments with aluminium-lime application show that *Brachiaria decumbens, B. humidicala, B. mutica, Andropogon gayanus, Panicum maximum* and *Digitaria decumbens* can tolerate high levels of aluminium (Skerman and Riveros 1990). *Cenchrus ciliaris* was most affected by Al concentration up to 4 ppm, followed by *Hyperrhenia rufa* and *Panicum maximum* (Spain 1979).

**Resistance to diseases and pests**

Pesticides and insecticides continue to have an occasional place in forage production. However, breeding for resistant varieties of plants is a preferred approach. For grass and ground legumes, resistant cultivars have been bred, such as Khon Kaen Stylo which is resistant to *Anthracnose.* *Digitaria decumbens* has been severely attacked by rust *Puccinia oahnensis;* resistant *Digitaria* species are being investigated. Fodder shrubs and trees are generally quite resistant to disease and pests. Nevertheless, a psyllid
(Heteropsylla cubana) outbreak reported in Hawaii in 1984 and in Asia in 1985, devastated Leucaena leucocephala (NFTA 1989). A stable resistant Leucaena variety was subsequently bred. In some areas in Indonesia, Gliricidia sepium becomes infested with aphids (Aphis craccivora) at the onset of the rainy season. These aphids cause blackening of the leaf surface and in severe cases causes shedding of the young leaves (Nitis 1992). Three provenances of G. sepium which are resistant to aphid infestation have been defined (Nitis et al 1991b).

**Symbiotic nitrogen fixation**

Tropical legumes fix 30 to 300 kg of nitrogen. Under rubber in Malaysia, the leguminous cover crops can fix N from 300 to 350 kg N/ha/yr (Hamilton and Pellay 1941). In Sri Lanka it was reported that pasture legumes can fix over 150 kg N/ha/yr, while the shrub legumes Leucaena and Gliricidia can fix N up to 400 kg/ha/yr (Jayawardana 1988). Some grasses in association with selected strains of N fixing bacteria may increase the nitrogen fixation. *Paspalum notatum* in association with Azotobacter paspali can increase fixation by 93 kg N/ha/yr (Day et al 1975); while *Digitaria decumbens* in association with *Spirillium lipoferum* increase fixation by 131.12 g N/ha/d (Quesenberry et al 1976). *Azospirillum brasilense*, a potential nitrogen fixing agent, has been found in the rhizosphere of 95 per cent of the grasses collected in northern Australia.

**Planting material**

**Seed**

Seeds should be obtained from reliable sources and wherever possible be certified seed which minimises contamination from weeds and guarantees germination and viability. Before planting, seeds should be tested for germination and seedling emergence on a small seed bed made from a soil-sand mixture (75:25 ratio), because seedling emergence is usually 30 per cent lower than seed germination reported for seeds stored for more than one year at room temperature.

Most legume seeds have a high percentage of seed which will not germinate even under favourable conditions. Hard seededness is a natural protective mechanism to ensure survival through adverse weather conditions and varies between 60 and 90 per cent, and under natural conditions, declining over time. Treatments to break dormancy include:

**Scarification**

Abrasion of the seed coat will increase permeability to water. This is done by rubbing the seeds slightly between two pieces of sandpaper until the seed coat looks shiny.

**Chemical treatment**

Dissolving some of the substances inhibiting germination. This is done by soaking the seeds in alcohol or acetone for one hour. Sulfuric acid treatment is not recommended on farm. Soaking in warm (50°C) glycerine for one hour increases germination of *Pueraria phaseoloides* seed from 10 to 50 per cent and that of *Centrosera pubescens* from 9 to 16 per cent, while those of *Flemingia macrophylla* or *Calopogonium mucunoides* do not respond.

**Hot water treatment**
Hot water or boiling water can be used to break the dormancy of some seeds. The dormancy of *Leucaena leucocephala* seeds is broken by heating the seeds to 80°C for four minutes or by adding them to boiling water for 30 seconds. Dormancy of *Acacia aneura* seeds is broken after boiling for three minutes.

**Infrared lamp irradiation**

Illumination and radiant heat from an electric lamp can break dormancy of some seeds. Reportedly the germination of *Calopogonium* seeds was enhanced by exposure to a 150 watt Philips lamp for eight hours and to a 250-watt Osram lamp for 16 hours; *Pueraria* by a Phillips lamp for one hour and an Osram lamp for two hours; *Centrosema* under Osram for 16 hours and *Flemingia* for only 7.5 minutes under a Phillips lamp.

**Inoculation**

Legume seeds should be inoculated with viable rhizobia of the correct strain to provide early and effective nodulation in the field. Three hundred organisms per seed is regarded as minimal requirement to ensure satisfactory nodulation (Vincent 1970). To protect the inoculum from sunlight and dryness after sowing, inoculated seed can be coated with lime or rock-phosphate using 45 per cent (wt/vol) gum arabic solution or four per cent pure methyl cellulose solution.

**Vegetative propagation**

Some grasses such as *Pennisetum pupureum* do not produce viable seeds so propagation is carried out by planting cuttings. Cuttings are, one to two centimetres in diameter and contain three to four nodes cut from the middle part of a 12-month-old stem.

For faster establishment, some grasses that produce seeds such as *Panicum maximum* or *Cenchrus ciliaris*, can be propagated by tillers. At the start of the rainy season a two-year-old bunch of grass is split into clones containing two tillers which are cut above the bud to reduce water loss.

Some fodder shrubs such as *Gliricidia* and fodder trees such as *Erythrina* are better propagated by stakes, which show survival rates of more than 85 per cent. *Leucaena* and *Artocarpus* do not suit this technique. Stakes with thick and moist bark survive better than those with thin and dry bark.

The size of a shrub stake is usually two to three centimetres in diameter and 125 cm in length; while the size of the tree stake is usually four to five centimetres and 200 cm. Stakes can be stored in a bundle of 25 for shrubs and 10 for trees under shade for six months. Stakes lead to lateral roof development and are better suited to shallow soils, while seeds lead to tap root development and are better suited to deep soils.

**Planting system**

**Time of planting**

For wet soils, planting should be carried out in early to mid dry season, to avoid floating and washing away of seeds and seedlings during the wet season. For rain-fed soils, planting should be carried out just before, or after the first rains have fallen. Small seeds which must be planted close to the soil surface, need the moisture and warmer temperature which usually occur with the opening rains for germination (O'Reilly 1987). The high humidity and low evaporation favour seedling survival at this time of the year.
Depth of planting

On prepared seedbeds, drilling seeds or planting in farrows is more effective than broadcasting because the seed is placed at the right soil depth. Small-seeded grasses and legumes are sown at 1.2 cm soil depth in medium to heavy clay soil, or 2.5 to 3.8 cm in sandy soils. Large seeded legumes can be sown at 3.8 to 6.3 cm soil depth. For grass cuttings the depth of planting can be 4.0 to 6.0 cm when planted up right and 2.5 to 4.0 cm when planted horizontally. For grass tillers the depth of planting can be 2.5 to 3.5 cm to cover the tiller base. For fodder shrub and tree stakes, the depth of planting can be 15 to 25 cm, and 20 to 30 cm, respectively.

Density of planting

Higher seeding rates can be adopted in the higher rainfall areas to suppress weeds while in the low rainfall areas Middleton (1970) showed that seedling density of Desmodium intortum, Macroptilium atropurpureum and Setaria ancept was proportional to sowing rate and only a high legume sowing rate maintained a satisfactory proportion of legumes in the mixed pasture. Increasing the sowing rate of the species in the mixture altered the botanical composition, but not the final dry matter yield.

For some grasses propagated by tillers or cuttings, the tiller is planted at 10 cm spacing within the row and at 10 cm spacing between the rows. The cutting is planted at 25-50 cm spacing within the row and 50-100 cm spacing between the rows. Planting density of the stakes of fodder shrubs and trees should be 10 cm between shrubs and five meters between trees when planted along the fence boundary, 50 cm within the rows and five to six meters between rows when the shrubs are grown as alley crops, 100 cm within the row when used as a terrace guard row, and two square meters for the four shrub stakes and five square meters for the four tree stakes when grown in cluster.

Ease of planting

Seed which has been soaked in water should be dried before sowing. To prevent clogging of planters, seeds should be mixed thoroughly with sand (3:1 seed: sand ratio) before sowing. Seeds with hairy coats should be mixed with sand to prevent being blown away by wind during sowing. Stakes of fodder shrubs and trees which have been stored for some time should be cut at the base so that the fresh tissue can be in direct contact with the soil.

Protection against intruders

Following sowing, split fresh coconut or rice bran should be spread around the field, so that the ants will eat the coconut meat or the rice bran, instead of removing some of the seeds. Insecticide use is not recommended, as it will kill chickens which usually roam around the fields of smallholder farms. All chickens should be kept in cages by the farmers until the seedlings emerge. Straight after broadcasting or farrow sowing, coconut fronds or shrub branches should be dragged around the sown area to cover the seeds with soil, so that they are not easily seen and eaten by wild birds or roaming chickens. Live fencing around the field should be constructed to prevent stray animals getting in.

Planting in integrated farming system

In intercropping systems, shrubs and trees are grown along with cash crops in the form of windrows (such as, nurse trees in timber crops), between cash crop plants (shade trees in the coffee plantations), with the cash crop plants (such as climber trees for vanilla), or scattered among the cash crop plants (such as
cash crop plants (such as climber trees for vanilla), or scattered among the cash crop plants (such as *Sesbania grandiflora* in the corn and cassava). The shrubs and trees are lopped, particularly to prevent overshading the cash crops. For the timber crops, lopping is not necessary, because the timber plant will grow over the nurse trees.

In the embankment system in the wetland farming areas in Indonesia, some farmers grow shrubs, but not trees, on the border/bund of embankment fields. *Sesbania grandiflora* is the shrub most commonly grown on the bund of rice fields. On the bund of dryland farming areas in the coastal areas, banana, coconut, jackfruit and mango are common, whereas on the bund of dryland farming areas in the higher altitudes (above 500 m), *Erythrina variagata*, *Caliandra* and *Flagellaria indica* are common.

On critical and sloping lands, shrubs and trees are grown in rows to form a terrace. Experiments in the Philippines showed that planting *Leucaena* in double hedgerows across the slope will cause the formation of natural terraces across the slope after three years of continuous cultivation. Along the roadsides and surrounding public fields, shrubs (such as *Leucaena*) and trees (such as *Tamarindus*) are grown. Shrubs and trees (for example, banana, bamboo, Sago palm, and *Erythrina lethosperma*) are also grown on the banks of water catchments, creeks, rivers and other waterways.

In the embankment system in the wetland farming areas in Indonesia, some farmers grow shrubs, but not trees, on the border/bund of embankment fields. *Sesbania grandiflora* is the shrub most commonly grown on the bund of rice fields. On the bund of dryland farming areas in the coastal areas, banana, coconut, jackfruit and mango are common, whereas on the bund of dryland farming areas in the higher altitudes (above 500 m), *Erythrina variagata*, *Caliandra* and *Flagellaria indica* are common.

In embankment systems, shrubs and trees are usually found in areas not suited for cash crop production. The number of plants per cluster varies from 10 to 50. One tree cluster could consist of four trees as poles for livestock stables and poles for bird-watching huts in the field. Any shrub or tree can form a cluster. For the poles of the livestock stall and bird watching hut, *Lannea*, *Erythrina* and *Hibiscus* are most commonly used.

In cluster systems, shrubs and trees are usually found in areas not suited for cash crop production. The number of plants per cluster varies from 10 to 50. One tree cluster could consist of four trees as poles for livestock stables and poles for bird-watching huts in the field. Any shrub or tree can form a cluster. For the poles of the livestock stall and bird watching hut, *Lannea*, *Erythrina* and *Hibiscus* are most commonly used.

In fenced systems, farmers generally use live fences to mark land boundaries and for livestock yards. Soil is tilled and seeds are planted in a windrow at two-centimetre depth. When cuttings are planted, the length is 0.5 to 1.5 m for the shrubs planted at 10 cm spacing, and 1.5 to 2.0 m length for the trees planted at five meter spacing. Seeds are planted during the rainy season, whereas cuttings are planted at the onset of the rainy season. Branches are lopped regularly, but the trunks are only cut occasionally, at 10 to 20 m height.

In backyard systems, any shrubs and trees are grown behind houses. In most Indonesian villages, such shrubs and trees are also grown for traditional medicines, vegetables and other household requirements.

In forest systems, lumber and pulpwood demand leading to indiscriminate cutting of forest has caused programs to be developed to plant accompanying shrubs and trees for firewood and livestock feeds.

In savannah semi-extensive farming systems, shrubs and trees grow singly or in a cluster among the natural grass. When grass is insufficient, ruminants browse the tree leaves, and by the end of the dry season, it is not uncommon to find that their diet consists of tree leaves exclusively.

**Fertiliser application**

**Types of fertiliser**

Fertiliser can be classified into inorganic or chemical and organic or natural fertiliser. Inorganic fertiliser can be in the form of acid fertiliser such as, superphosphate, non-acid fertiliser, such as, superphosphate and lime superphosphate and neutral fertiliser, such as a mixture of lime and some neutral mineral compound. Organic fertiliser can be in the form of barnyard manure and green manure.

Rhizobium species are sensitive to acid fertiliser. Mixing superphosphate with inoculated legume seed for even one hour before planting, markedly reduces seedling emergence, and contact for 24 hours completely kills the rhizobium. Contact with non-acid fertiliser is not harmful.
Completely kills the rhizobium. Contact with non-acid fertiliser is not harmful.

Green manure from readily broken leaves, such as, *Gliricidia* leaves, should not simply be spread on the soil surface, since its nitrogen content will diminish by 30 per cent in 60 days. Such loss of nitrogen can be reduced by ploughing or burying the green leaf under the soil. Furthermore, feeding of shrub and tree fodders to ruminants and using their manure as fertiliser is a more efficient utilisation of the carbon and nitrogen (Nitis 1986). Goat manure contains more N than cattle manure and decomposes at a slower rate than cattle manure.

**Rate of application**

There is an initial nutrient barrier which must be broken first by relatively heavy fertiliser application for establishment in most soils. Then in subsequent years the requirement for maintenance can be lower, the rate of application may be about 25 to 60 per cent of the initial application.

At least 11 kg/ha of nitrogen should be included in the grass-legume mixture (Skerman et al 1988). This is because, between planting and the appearance of the first active nodule, there is a hiatus, during which added N would be beneficial for legume establishment. Application of 123 to 493 kg/ha of superphosphate assists establishment, since legumes and their rhizobium require high levels of phosphorus. One exception is *Stylosanthes* species, which can efficiently extract P from low phosphate soils. Potassium is not always limiting, but under high production it is usual to add about 132 kg/ha muriate of potash per year. Molybdenum is essential for legume nodulation and it is usually applied at 210 to 420 kg/ha as molybdenum trioxide. Sulfur may also be deficient in the tropics, and corrected from the S in superphosphate. Copper is supplied as copper sulphate at about eight kilograms per hectare, zinc as zinc sulphate at eight kilograms per hectare, and boron as borax at 22 kg/ha. The specific requirements of the situation need to be determined.

**Renovation**

Pastures decline in production after four to six years due to soil compaction, nutrient imbalances and competition for space. The renovation process is simply, ploughing old pasture and re-sowing, or direct sowing with improved cultivar of the old species or with different species into degraded pasture. For most of the grass and legume species, renovation can be done by using seeds, although with some grass species such as *Pennisetum purpureum* renovation can be done vegetatively.

**Developments in production systems**

**Companion, alley, relay and related cropping systems**

Forage for livestock can be intercropped with food crops for humans. Experiments in Thailand showed that sowing *Stylosanthes guianensis* at two kilograms per hectare, 10 days after sowing an early upland rice crop, might be expected to provide an additional three tons per hectare of leguminous forage with little or no reduction in rice yield (Shelton and Humphreys 1975a, b). In Indonesia, *Stylosanthes guianensis* sown under cassava increased the forage yield 115 per cent without affecting the tuber yield of the cassava (Nitis and Suarna 1976). Feeding experiments showed that Bali cattle fed *Pennisetum purpureum* mixed with *Stylosanthes guianensis* (50:50) gained 42 per cent more live weight than those fed Pennisetum only (Nitis 1981).

With the presence of a companion crop, soil which is otherwise bare after the food crop harvest, is protected from soil degradation and fertility is increased from the nitrogen fixed by the *Stylosanthes* which can be equivalent to urea at 20 kg/ha in one food crop season (Nitis 1977).
Alley cropping is the growing of cash crops between rows of frequently pruned leguminous shrubs. Foliage can be used for green manure or livestock feed. Experiments in Africa showed that corn continuously ally-cropped with *Leucaena* produced 0.3 t/ha more than corn not alley-cropped. Furthermore, when the corn is rotated with grazing, the corn production is 0.4 t/ha higher and the nitrogen contributed by the *Leucaena* is 155 and 178 kg/ha, respectively (Fleury 1985). To balance the system, it has been suggested that only up to 25 per cent of the foliage should be used as livestock fodder, and that a rotation of four years cropping be followed by two years grazing (Atta-Krah 1990). Experiments in the hilly areas of the Philippines showed that *Leucaena* grown in two hectares of fruit trees can support 20 head of growing cattle when the *Leucaena* is harvested every 40 to 60 days (Moog 1985).

Relay cropping involves upland rice and leguminous grain crops (Nitis 1995). The leguminous residue remaining after grain harvest can be fed to ruminants with little or no detrimental effect to the productivity of the system. In fact nutrient cycling may be accelerated.

In bench terrace systems improved grass species are planted along the terraces of steep sloping land (Nitis 1995). The main crop is planted on the flat area of the terrace. The grass strip reduces the water abrasion of the sloping land and when cut regularly can supply forage for livestock.

The Taungya system derives from a Burmese word meaning hill cultivation, in this case, shifting cultivation. It involves growing strips of fodder shrub and trees with cash crops between a band of timber trees on the sloping land used for forestry (Wiersum 1982). Such systems can supply more livestock feed, more food from the cash crop, and more firewood to the farmer working in the forestry department without compromising timber yields.

The Surjan system uses multipurpose shrubs and trees grown on raised bed strips with cash crops on low-lying areas (Nitis 1995).

**Pastures and intensive systems**

The sloping agricultural land technology system consists of alternative strips of annual food crop and strips of fodder shrub or tree legumes along the contour line of steep lands. In the Philippines, where the system originated, the land used is divided into 40 per cent for agriculture, 20 per cent for forestry and 40 per cent for livestock, particularly goats in a cut and carry system.

The intensive feed gardens use fodder shrub and trees in pure stands or combined with grasses and managed intensively to provide fodder for livestock. In Africa, annual yields of 30 t/ha DM are possible from this system (ILCA 1988).

Improved pasture systems are based on improved grass and ground legumes sown singly or with the native pasture in the fallow, communal, private grazing land and degraded land. In Thailand, large areas of roadside and communal grazing land have been sown broadcast with *Stylosanthes* species thereby improving forage supply, helping to familiarise farmers with new species, and disseminating seed to adjacent areas (Gutteridge 1985). Experiments in Indonesia showed that over-sowing native pasture with *Centrosema*, *Stylosanthes*, *Calopogonium*, and *Macroptilium* can increase the stocking rate six times (Till and Blair 1982).

The productivity of native pasture under coconut can be increased by improving the pasture. Experiments in Thailand showed that cattle grazing on improved grass-legume pastures (*Brachiaria* and *Centrosema*) can produce live weight gains more than twice those grazing on native pasture at the same stocking rate.

The Savannah system is an integration of shrubs and/or trees either singly or in clusters among the natural
The Savannah system is an integration of shrubs and/or trees either singly or in clusters among the natural grass in an extensive dryland area in the dry tropics (Nitis 1986). The natural pasture can be sown with improved grass-legume pasture and the native trees can be replaced with timber trees (savannah timberland) or the native trees can be replaced with fodder shrubs and trees (savannah fodder land).

The home plot system integrates farmhouse with shrubs and trees, pasture, food crop and livestock in a small (0.25 ha at least) area of land (Anon 1990). In this system the border of the farm compound is totally planted with shrubs and trees, with a strip of grass inside the border. The area inside the border is used for housing the farmer's family, livestock shed, fodder shed, for growing food crops and forage and fodder.

One example of an integrated system is the three strata forage system (TSFS) which consists of 0.25 ha land divided into a core, peripheral and circumference area (Figure 9.2). The core area is planted with the main crop commonly grown by local farmers. The surrounding (peripheral) area is planted with grass and ground legumes as the first stratum; the border around the peripheral (circumference) area is planted with shrub legumes as a second stratum and fodder trees as a third stratum (Nitis et al 1989). Grass and ground legumes are harvested for livestock feed during the four month wet season; shrub legumes during the four-month early dry season, and fodder trees during the four-month, late dry season.

Under TSFS food crop yields decrease by less than the reduction in area for the cash crop and forage production increases by 90 per cent and is of higher crude protein content. Cattle gain about 13 per cent more live weight at stocking rate increases of 30 per cent, yet time spent caring for cattle is reduced. Other production efficiencies, social, environmental and economic benefits also apparently accrue from TSFS (Nitis et al 1989; TSFS Team 1993).
Conclusion

In addition to production and related economic benefits of the various livestock feed production systems, environmental benefits also exist. Forage plants use carbon dioxide, synthesise carbohydrates and oxygen is produced as a by-product of respiration. Perennial grass pasture can convert CO$_2$ into organic matter at an annual rate of 53 t/ha, which is equivalent to the CO$_2$ emitted by cars travelling a total of 213,000 km (Fisher 1994). Through the roots, nutrients are absorbed from the soil and in the case of leguminous species, gaseous nitrogen in the air is metabolised in root nodules to form plant protein. The dead plant parts in the form of humus return nutrients to the soil.

Smallholder dairy production relies on a reliable quality and quantity of feed which can often be produced within existing farming systems. Technologies have been determined and the challenge is to now promote wider use of technologies to allow greater and more efficient production of milk from small farms in the tropics.

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Production of *Gliricidia sepium* fodder alley cropped with cassava.

Production of elephant grass and *Sesbania glandiflora* shrub fodder on the bund of the soybean field.
Production of elephant grass on the bund of the rice field.

Production of improved grass-legume pasture under coconut plantation.
Chapter 10
Forage utilisation
L.R. Humphreys

Objectives for forage utilisation
The response of the pasture to cutting or grazing
The delivery of nutrients from the forage
Adjusting animal demand and forage supply
Providing continuity of forage supply
Conclusion
References

Objectives for forage utilisation

The increased forage production resulting from the strategies outlined in the previous chapter creates a potential for increased dairy output. The way the pastures are managed decides whether the effort and resources invested in improving the feed supply bring returns in the form of better milk output and the raising of more young stock. The principal objectives of forage utilisation (Humphreys 1991) are to:

- cut or graze the pasture in ways which (1) maximise the delivery of nutrients to the animal, (2) sustain the vigour and persistence of the pasture, (3) maintain cover as a defence against erosion and (4) preserve a desirable botanical composition
- adjust the animal demand in line with the forage supply
- arrange continuity of forage supply in order to maintain animal production and minimise animal stress through (1) providing a sequence of feeds of differing seasonal utility, (2) conserving or purchasing feeds, and (3) modifying the pasture environment through irrigation and fertiliser practice.

The response of the pasture to cutting or grazing

The way pastures are cut or grazed powerfully influences the amount of growth and the persistence of the sward. There are three main ideas(Humphreys 1997).

Firstly, when growing conditions are good, the pasture yield is decided by whether there is enough leaf surface there to intercept the sunlight. It follows that if the number of the animals grazing the pasture is not excessive, so that a leafy sward which covers the ground is maintained, pasture yields will be high, and soil erosion (Humphreys, 1994) will be minimal. Similarly if pastures are cut infrequently or at a height which allows some leaves and buds to stay below cutting height, more sunlight is trapped and yields are high. Thus in Sri Lanka, Goonewardena et al (1984) found that if *Panicum maximum* was cut every 10 days the yield was 8.3 t/ha, and 15.5 t/ha if the cutting interval were increased to 30 days.
Similarly cutting at five centimetres height gave 9.4 t/ha whilst cutting at 15 cm height increased the yield to 13.5 t/ha.

Another illustration comes from Ibadan, Nigeria (Figure 10.1). *Leucaena leucocephala* was grown in rows with varying space between them. Increasing the interval between cuts from six to 12 weeks when the shrub was grown close together at 0.5 m interrow spacing raised the dry-matter yield from 17 t/ha to the very high yield of 38 t/ha. The decrease in yield associated with wide row spacing lessened beyond 1.5 m due to greater compensatory growth and survival of individual plants at the two-meter spacing.

When *L. leucocephala* is grown to produce a fodder bank for the dry season the cutting height will influence how much fodder accumulates. When the shrub was grown at Samford, southeast Queensland and cut at 30 cm height in February, the peak accumulation of edible dry matter was only 2.4 t/ha; this increased to 4.2 t/ha if cut at 120 cm (Figure 10.2).

Second, the amount of pasture material which senesces increases as the rate of pasture growth exceeds the rate of removal by grazing or cutting. Senescent forage is most evident when plants experience drought or cold; it is not always understood that the rate of plant senescence is fastest when the rate of pasture growth is highest. Under-using the pasture therefore wastes a good deal of material which is eventually rejected by animals and adds to soil litter. The leafiness of the pasture also decreases with age, which reduces the nutritive value of forage. It needs to be emphasised that the first objective of pasture management is to maximise the delivery of nutrients used by the animal and NOT to maximise pasture growth.

The greatest yield of utilised forage occurs at levels of grazing or cutting which offer young grass to stock; the deterioration in quality with age of material is less for legumes than for grasses.

Thirdly, lenient grazing or cutting management will favour the persistence of erect growing grasses such
as *P. maximum*. Pastures of *P. maximum* that are cut or grazed too intensively are short-lived, become invaded by weeds such as *Pennisetum polystachion* and require frequent replanting. On the other hand, creeping plants, such as *Arachis pintoi*, are favoured by quite heavy grazing, since they maintain a high density of buds close to the soil surface and their leaves are less shaded by tall companion species if the pastures are well grazed.

### The delivery of nutrients from the forage

The targeted nutritive value influences the decisions a farmer makes about how frequently the pasture might be cut. Frequent cutting gives young, leafy forage of high nutritive value and lower yield; infrequent cutting gives more stemmy forage with lower quality leaf material and higher yield.

Much depends upon the relative price of cut forage and concentrates. Cut forage may bring US 1.5c/kg in Indonesia (Soewardi 1986) or US 2c/kg in Thailand (Lekchom et al 1989) where concentrates cost about 16.5c/kg. As concentrates become more expensive a greater premium for forage quality should apply. Operators who cut forage from roadsides and waste lands for sale to dairy farmers will usually seek to maximise the yield and the ease of cutting.

The speed at which the pasture grows influences its nutritive value and the attainment of a yield worth cutting. Thus in the mid-country region of Sri Lanka, Chadhokar (1983) recommended cutting *P. maximum* every four to six weeks in the wet season and six to eight weeks in the dry season. At Muaklek in Thailand fertilised grasses which were strip-grazed every 24-27 days during the rainy season, provided leafy pastures with 12 to 15 per cent crude protein and 60 to 65 per cent digestibility and maintained an average growth rate of 80 kg dry matter/ha/d. The pastures were grazed when they grew to 50-60 cm height and stock were moved on when the pastures were about 15 cm high (Tudsri and Sawasdipanit 1993). In Johore, Malaysia a shorter grazing interval of 17-19 days was recommended (Choo 1993).

What are the modern concepts of nutritive value? These have been related to the energy and protein status of the forage, provided the supply of essential minerals is adequate. A good deal of attention is given to the intake of forage and its digestibility, and management which is directed to increasing the intake of forage (for example, providing leafy forage, supplying legumes which have a fast rate of passage through the rumen), thus benefiting milk production. Recently the actual delivery of nutrients from the rumen and the efficiency of their use has excited more attention (Poppi et al 1997). The balance of nutrients required by the animal is set by its physiological state, which is high for pregnant, lactating animals and lower for dry stock.

The first need is to ensure that the rumen is functioning adequately in terms of the intake of forage being processed and digested. Many tropical grasses are low in protein content, and the intake of these grasses is readily increased by supplying higher protein sources in the diet, for example, legumes, protein supplements such as cottonseed meal, or urea-treated material. In these circumstances the protein production by the microbial population of the rumen is lifted to acceptable levels. Tropical grasses also tend to have low values for non-structural carbohydrates. Therefore, choosing feeds with better characteristics in this respect, such as *Pennisetum purpureum* and forage *Sorghum* spp increases not only the level of rumen fermentation but the production of microbial protein. The response by an animal to extra protein is greater when increased intake of metabolisable energy (ME) occurs.

Protein is often used wastefully by ruminants, and perhaps only 11 to 16 per cent of the protein ingested ends up in the final product (Poppi et al 1997). At high levels of protein supply a good deal of ingested protein is lost across the rumen wall as ammonia, and the key ratio for efficient protein use is that forage should not contain more than about 210 g crude protein per kilogram of digestible organic matter. This
represents a degradable crude protein (CP) available energy relationship for rumen organisms of 13.3, 11.9 or 9.3 g CP/MJ ME respectively for protein degradability of 1.0, 0.9 and 0.7. Much depends on the degradability of protein which varies greatly among forages. Table 10.1 shows the differing solubility of leaf and stem fractions of a range of plants; legumes like *Desmodium intortum* with low protein solubility provide more ‘by-pass’ protein to increase milk production directly.

**Table 10.1.** Protein solubility (%) of leaf and stem of legumes and N-fertilised grasses (*Aii and Stobbs 1980*).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Leaf</th>
<th>Stem</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Desmodium uncinatum</em></td>
<td>5.3</td>
<td>36.3</td>
</tr>
<tr>
<td><em>D. intortum</em></td>
<td>7.6</td>
<td>15.9</td>
</tr>
<tr>
<td><em>Aeschynomene indicata</em></td>
<td>21.0</td>
<td>48.5</td>
</tr>
<tr>
<td><em>Macroptilium atropurpureum</em></td>
<td>40.8</td>
<td>52.9</td>
</tr>
<tr>
<td><em>Macrotyloma uniflorum</em></td>
<td>44.7</td>
<td>54.5</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Setaria sphacelata cv Narok</em></td>
<td>18.6</td>
<td></td>
</tr>
<tr>
<td><em>S. sphacelata cv Kuzungula</em></td>
<td>19.3</td>
<td>44.2</td>
</tr>
<tr>
<td><em>Pennisetum clandestinum</em></td>
<td>24.0</td>
<td></td>
</tr>
<tr>
<td><em>Digitaria decumbens</em></td>
<td>24.4</td>
<td>37.9</td>
</tr>
<tr>
<td><em>Panicum maximum</em></td>
<td>25.7</td>
<td></td>
</tr>
<tr>
<td><em>Chloris gayana</em></td>
<td>29.7</td>
<td>53.6</td>
</tr>
<tr>
<td><em>Panicum coloratum</em></td>
<td>33.4</td>
<td>43.4</td>
</tr>
<tr>
<td><em>Brachiaria mutica</em></td>
<td>33.5</td>
<td>37.7</td>
</tr>
</tbody>
</table>

Protein protection appears to be related to the content of condensed tannins which form complexes with plant proteins and are then dissociated in the acid conditions of the abomasum. The absence of tannins in the shrub legumes *Sesbania* spp and *Albizia lebbeck* disadvantages them relative to *Leucaena leucocephala*; on the other hand too high a level of condensed tannins reduces plant intake, decreases rumen ammonia and depresses the post-ruminal absorption of protein.

Further illustrations of the components of nutritive value are given later in the chapter.

**Adjusting animal demand and forage supply**

At the lower levels of forage supply, milk production responds sharply to an increase in the forage offered. As the supply increases animals eat more selectively, which improves their diet, but a point is reached where further increases in forage supply do not improve milk production and may even reduce it.

This is illustrated for Friesian Holstein cows at Atherton, Queensland in Figure 10.3. These cows were grazing *P. maximum var. trichoglume-Neonotonia wightii* pastures and received concentrate supplements at zero to six kilograms per cow per day. The pasture on offer was measured as the dry matter of the green...
fraction on offer. Milk yield of unsupplemented cows increased steeply, up to about 1500 kg green dry matter (GDM) per hectare presented to the animals, and showed a slight further increase to about 2000 kg/ha, and little increase beyond that figure. The relationship between available pasture and milk yield weakened as the level of concentrate feeding increased and less pasture was consumed.

Figure 10.3. Relationship between milk yield [vertical scale - FCM yield (kg cow\(^{-1}\) d\(^{-1}\))] and GDM on offer [horizontal scale - Pasture on offer (kg GDM ha\(^{-1}\) x1000)] of Panicum maximum var trichoglume/Neonotonia wightii for different levels of concentrate feeding (Cowan et al 1975).

Most smallholder dairy farmers integrate a series of feeds with pastures which are cut or grazed. Where year-round grazing applies, farmers should be aware of how the stocking rate (SR) which is, the number of animals grazed per unit area, influences milk yield. Milk yield per cow decreases as SR increases, although the milk yield per hectare may increase because of the extra number of cows carried. This is illustrated for three experiments in Figure 10.4. In the upper part of the diagram it may be noted that milk yield...
yield per cow decreased as SR on *P. maximum* pastures increased from two cows per hectare to 3.5 cows per hectare. However, milk yield per cow was greater if 400 kg N fertiliser were applied than if pastures received 200 kg N fertiliser per hectare. Milk yield per cow also decreased at the higher SR on the less productive systems of Colman and Holder (1968) and Colman and Kaiser (1974).

It is emphasised again that the response of milk yield to the amount of pasture available or fed is most sensitive when forage is in short supply. In north Queensland (Figure 10.5), the change in milk production per cow as stocking rate increased by one cow per hectare was a reduction (in year two) of 2.4 litres per cow per day in mid-summer December, but the reduction was much greater as the season advanced, and reached 6.1 litres per cow per day, in July.

The dairy farmer needs to adjust the forage allowance according to its nutritive value. Animals should be given an opportunity to reject the lower quality material offered, so that the ratio of utilisation (feed offered/feed consumed) may be quite low if milk production is to be maintained. Forage allowance is further modified by the size of the animal and the notional daily intake as a fraction of body weight. A crude rule of thumb is:

$$\text{Desirable forage allowance} = \frac{\text{Intake as a fraction of body weight}}{\text{Desired ratio of utilisation}}$$

Thus for a 300 kg cow eating three per cent of body weight each day and a ratio of utilisation of 0.45, the forage allowance is 20 kg dry matter per day.

### Providing continuity of forage supply

#### Management

Dairy farmers manage the feed supply so as to avoid or to lessen shortages in order to:

1. minimise animal stress, maintain body condition and prevent animal deaths
2. promote successful calving, and
3. sustain milk secretion and the growth of offspring.

Much depends on whether a premium is paid for the year-round supply of fresh milk, which is more costly to the farmer than a system where seasonal supply of milk is the norm.

A good deal of animal stress can be avoided by seasonal calving. Thus, mating female stock at the period of the year which will ensure that the peak demand for forage during late pregnancy and early lactation will coincide with the flush of forage growth. The sale of surplus offspring can be timed to avoid...
additional animal demand when forage is in short supply.

One approach to reducing the seasonal feed shortage is by changing the environment in which the pasture grows to lengthen favourable conditions for pasture production. The timing of N fertiliser applications can be used to extend the growing season. The growth response per unit of fertiliser applied will be less at the beginning and at the end of the growing season than if applied during the peak of the season, but the additional forage grown is sure to be eaten.

Moisture availability can also be changed by fallowing and storing water for later forage crop planting. The more expensive option is to use irrigation in the dry season; this is feasible when the price of dairy products allows water to be used on pasture rather than on crops. In the subtropics and the high altitude tropics production can be lifted greatly by growing irrigated temperate type pastures, which give much higher quality forage than is possible with tropical type pastures (Chopping et al 1982).

**Conservation: Silage**

The second major strategy is to conserve surplus forage or crops as hay or silage for use later when feed is in short supply. Hay from tropical grasses is not widely produced, since it is difficult to combine a good yield with satisfactory nutritive value; grasses making vigorous growth rapidly decline in protein content and digestibility decreases as the proportion of stem increases. A prime difficulty is the incidence of rain which interrupts the drying process in the field and causes spoilage of the hay and reduced growth of the pasture due to it being smothered by the cut material. Legume hays are more attractive, but suffer the same risk of spoilage unless grown as special crops on stored soil moisture. In northeast Thailand *Crotalaria juncea* may be planted on deep soils after the rice harvest and drying the cut forage detoxifies the alkaloid content (Kessler and Shelton 1980). Artificial drying of cut forage is regarded as too energy-intensive and costly for most smallholder dairy farmers.

Silage obviates the need for field curing and fodder crops such as *Zea mays* and *Sorghum* spp reliably produce acceptable silage. Silage is the product from a series of processes by which cut forage of high moisture content is fermented to produce a stable feed which resists further breakdown in anaerobic storage. The objective is to retain or augment the nutrients present in the original forage and deliver a silage accepted by livestock; this is usually attained through an anaerobic fermentation dominated by lactic acid bacteria.

Water-soluble carbohydrates are a primary substrate for the multiplication of lactic acid bacteria, which are initially present at low density in the forage, but which multiply rapidly during the initial ensilage process. Organic acids are generated which lower the pH of the material and inhibit the development of undesirable micro-organisms such as clostridia. The fast development of anaerobic conditions is favoured by cutting to short lengths and compressing the material, and a rapid fall in pH constrains the activity of the organisms that lead to spoilage.

Stable acceptable silages usually have a pH of 4.2 or less, lactic acid has 50 per cent or more of the total organic acids, butyric acid not greater than about 0.5 per cent of the dry matter, and NH$_3$N less than 10 per cent of total N.

Quality is first determined by the chemical composition of the forage ensiled. The choice of time of cut is crucial; very young forage will have a high moisture content and low yield; older material will have lower moisture content but may exhibit high fibre and low water soluble carbohydrate content. There are a number of management practices which facilitate the ensiling process.

The first of these is the exclusion of oxygen. The use of plastic wrapping, for example `Silawrap',
promotes anaerobic conditions and protects the material in storage. Tjandraatmadja (1989, Figure 10.6) in a series of studies showed the overwhelming significance of anaerobic conditions in making tropical silage production feasible; even lightly permeable polythene bags were inadequate as silage containers. The change in pH of ensiled *Sorghum bicolor* incubated at different temperatures progressed in a negative direction (Figure 10.6) if ensiled in oxygen impermeable bags, even at 40°C. However, silage quality was quite unacceptable, even at 20°C, if oxygen could leak into the stack.

As mentioned earlier, many tropical forages are low in water-soluble carbohydrate content. Wilting the forage before ensiling is advocated as a means of increasing these compounds on a fresh-weight basis and of reducing losses from effluent during storage. A further alternative is to add molasses. Legumes, as well as grasses, benefit from this practice, which is facilitated if a sugar mill is operating nearby and selling molasses as a by-product. Table 10.2 shows the effect of adding 2.3 per cent or 4.5 per cent molasses to *L. leucocephala*. Water soluble carbohydrate was only 6.3 per cent in the fresh material, and incorporating molasses led to a better fermentation, reduced pH, less volatile N and non-protein N, and increased lactic and acetic acids, which was consistent with the reduced population of yeasts and molds found in the silages receiving molasses.

Similarly in Malaysia Mohd Najib et al (1993) found that molasses addition was necessary when ensiling most tropical perennial grasses. *Setaria sphacelata* and *P. purpureum* had superior ensiling characteristics (Table 10.3), but satisfactory pH levels in silage from *Brachiaria decumbens*, *B. humidicola*, *Digitaria setivalva* and *P. maximum* only occurred when molasses was incorporated.

![Figure 10.6](image-url)

**Figure 10.6.** Changes in pH of silages fermented (a) in oxygen impermeable bags (I) and (b) permeable bags (P) at 20, 30 and 40°C (Tjandraatmadja 1989).

**Table 10.2.** Effects of molasses addition on composition of *Leucaena leucocephala* silage after 28 days (Alli et al 1984).
The most reliable silage of good nutritive value comes from *Zea mays* planted as a forage crop. Sweet corn stover, ensiled after the grain crop has been harvested, also makes acceptable silage. Table 10.4 indicates how the addition of molasses or of urea improves silage quality, but metabolisable energy levels were still low.

**Table 10.4.** The effects of molasses addition on silage quality.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Level of molasses addition (fresh weight)</th>
<th>0%</th>
<th>2.3%</th>
<th>4.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>4.7</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Dry matter (%)</td>
<td></td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Total N (%)</td>
<td></td>
<td>2.8</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Volatile N (% of total N)</td>
<td></td>
<td>5.6</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Non-protein (% of total N)</td>
<td></td>
<td>15.5</td>
<td>13.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Lactic acid (%)</td>
<td></td>
<td>2.0</td>
<td>4.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Acetic acid (%)</td>
<td></td>
<td>0.4</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Propionic acid (%)</td>
<td></td>
<td>0.2</td>
<td>0.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The low protein content of grass silages may be raised by incorporating legumes, but the content of water soluble carbohydrate needs to be carefully monitored. The practice can be recommended with confidence if molasses can be added. Table 10.5 shows the effects of incorporating 33 per cent fresh weight legume in 12-week regrowth of *Digitaria decumbens* cv Pangola. The forages were all fine-chopped and 4 per cent molasses were applied.

**Table 10.5.** Silage made from grass forages with or without molasses.

<table>
<thead>
<tr>
<th>Crop species</th>
<th>Nil molasses</th>
<th>4% molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
<td>Lactic acid</td>
</tr>
<tr>
<td>Setaria sphacelata cv Splendida</td>
<td>4.07</td>
<td>2.47</td>
</tr>
<tr>
<td>Brachiaria decumbens</td>
<td>5.07</td>
<td>1.08</td>
</tr>
<tr>
<td>Brachiaria humidicola</td>
<td>5.32</td>
<td>1.26</td>
</tr>
<tr>
<td>Digitaria setivalva</td>
<td>4.3</td>
<td>1.46</td>
</tr>
<tr>
<td>Pennisetum purpureum</td>
<td>3.96</td>
<td>2.53</td>
</tr>
<tr>
<td>Panicum maximum</td>
<td>4.71</td>
<td>1.84</td>
</tr>
<tr>
<td>Zea mays</td>
<td>3.72</td>
<td>2.72</td>
</tr>
<tr>
<td>S. vulgare x S. bicolor</td>
<td>3.68</td>
<td>3.75</td>
</tr>
<tr>
<td>S. alnum</td>
<td>4.40</td>
<td>na</td>
</tr>
</tbody>
</table>

1. Not available.
### Table 10.4. Chemical composition of sweet corn stover (% dry weight; Yusoff and Teoh 1993).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>75 days (fresh)</th>
<th>75 days (ensiled, plain)</th>
<th>75 days (ensiled with 1% molasses)</th>
<th>75 days (ensiled with 2% urea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>25.0</td>
<td>23.3</td>
<td>28.1</td>
<td>26.8</td>
</tr>
<tr>
<td>Crude protein</td>
<td>9.6</td>
<td>8.2</td>
<td>11.2</td>
<td>12.4</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>34.5</td>
<td>33.80</td>
<td>29.7</td>
<td>31.9</td>
</tr>
<tr>
<td>Crude fat</td>
<td>1.6</td>
<td>1.6</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Total ash</td>
<td>8.2</td>
<td>8.2</td>
<td>8.7</td>
<td>8.9</td>
</tr>
<tr>
<td>N-free extract</td>
<td>46.1</td>
<td>48.2</td>
<td>48.6</td>
<td>45.4</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.15</td>
<td>0.22</td>
<td>0.17</td>
<td>0.20</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.46</td>
<td>0.46</td>
<td>0.67</td>
<td>0.53</td>
</tr>
<tr>
<td>Metabolisable energy (MJ/kg)</td>
<td>7.82</td>
<td>5.86</td>
<td>6.27</td>
<td>6.09</td>
</tr>
</tbody>
</table>

The ensilage produced in airtight drums was of high quality, lactic acid dominated the fermentation, and effluent losses were negligible. Legume addition reduced the production of the unacceptable butyric acid. Cowpea (*Vigna unguiculata*) material had lower dry matter and N content than the two shrub legumes, and this was reflected in the quality of the silage produced.

### Table 10.5. Chemical composition of silages (Tjandraatmadja 1989).

<table>
<thead>
<tr>
<th>Component (g/kg DM)</th>
<th>Pangola</th>
<th>Pangola + <em>Leucaena</em></th>
<th>Pangola + <em>Gliricidia</em></th>
<th>Pangola + cowpea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (g/kg)</td>
<td>297</td>
<td>321</td>
<td>319</td>
<td>289</td>
</tr>
<tr>
<td>Neutral detergent fibre</td>
<td>624</td>
<td>517</td>
<td>522</td>
<td>583</td>
</tr>
<tr>
<td>Acid detergent fibre</td>
<td>388</td>
<td>340</td>
<td>338</td>
<td>377</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>236</td>
<td>177</td>
<td>184</td>
<td>209</td>
</tr>
<tr>
<td>Cellulose</td>
<td>342</td>
<td>283</td>
<td>282</td>
<td>330</td>
</tr>
<tr>
<td>Lignin</td>
<td>45</td>
<td>56</td>
<td>56</td>
<td>45</td>
</tr>
<tr>
<td>Ash</td>
<td>80</td>
<td>74</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td>Water-soluble carbohydrates</td>
<td>45.7</td>
<td>32.4</td>
<td>44.2</td>
<td>41.2</td>
</tr>
<tr>
<td>Total nitrogen (TN)</td>
<td>9.5</td>
<td>17.4</td>
<td>16.1</td>
<td>12.0</td>
</tr>
<tr>
<td>NH$_3$-N (g/kg TN)</td>
<td>90</td>
<td>85</td>
<td>78</td>
<td>92</td>
</tr>
<tr>
<td>pH</td>
<td>3.99</td>
<td>4.14</td>
<td>4.09</td>
<td>4.04</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>41.4</td>
<td>47.6</td>
<td>48.9</td>
<td>51</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>9.3</td>
<td>8.5</td>
<td>8.5</td>
<td>12.8</td>
</tr>
<tr>
<td>Butyric acid</td>
<td>5.5</td>
<td>3.5</td>
<td>0.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Ethanol</td>
<td></td>
<td>13.7</td>
<td>11.2</td>
<td>19.2</td>
</tr>
</tbody>
</table>
When assessing the value of silage, farmers need to ensure that it is forage surplus to animal requirements during the growing season that is being conserved. This is because any effect of reducing the forage supply on milk production in this period needs to be more than compensated by increased milk production when the silage or hay is fed. It should also be recognised that placing cows on a high plane of nutrition has persistent effects on milk production if the feeding level is subsequently reduced. A study by Davison et al (1982, Table 10.6) showed this effect in cows grazing at Atherton, Queensland which were supplemented with low or high levels of maize silage, with or without meat and bonemeal supplements for an eight week period. Meat and bonemeal had no persistent effect, but the higher level of maize silage feeding increased milk yield by one to two litters per cow per day, and benefited cow liveweight. In the eight week period following the cessation of silage feeding, when the level of pasture on offer decreased due to water stress, cows previously well fed performed better, and their higher liveweight and body reserves helped to maintain milk secretion. Similar effects of high body reserves might be expected to promote conception and reduce abortion. It should be noted that the high level of silage feeding reduced the time cows spent grazing the pasture; supplements are substitutionary as well as additive.

**Continuity of feed**

Often the most feasible and widely adopted approach to maintaining continuity of forage supply is to use a series of feeds of differing seasonal utility. The growth of the forage plants under differing conditions of temperature and moisture supply, and the rate at which nutritive value deteriorates as the growing season advances, are varied according to plant genetic makeup. The dairy farmer needs plants with a long growing season and superior nutritive value as standing hay.

**Table 10.6. Milk yield and composition, milk fatty acids, liveweight change and grazing time of cows during and after a period of supplementary feeding (Davison et al 1982).**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Low silage&lt;sub&gt;1&lt;/sub&gt;</th>
<th>High silage&lt;sub&gt;1&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total intake of supplement (kg DM/cow/d)</td>
<td>3.0 3.0</td>
<td>7.0 7.9</td>
</tr>
<tr>
<td>Milk yield (kg cow/d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeks 1-8</td>
<td>14.3 15.0 15.3 16.6</td>
<td></td>
</tr>
<tr>
<td>Weeks 9-16</td>
<td>13.6 14.0 15.0 15.0</td>
<td></td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.66 3.88 3.56 3.23</td>
<td></td>
</tr>
<tr>
<td>Solids-not-fat (%)</td>
<td>8.38 8.42 8.54 8.4</td>
<td></td>
</tr>
<tr>
<td>Milk fatty acids (molar % C4-C16)</td>
<td>53.8 54.6</td>
<td>57.3 57.1 61.5 56.6</td>
</tr>
<tr>
<td>Week 1</td>
<td>57.3 51.5 61.5 56.6</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>54.6 57.1 57.1 57.1</td>
<td></td>
</tr>
<tr>
<td>Liveweight change (kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 1-8</td>
<td>-15.4 2.0 11.4</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>15.0 -15.4 2.0 11.4</td>
<td></td>
</tr>
<tr>
<td>Grazing time (min/d)</td>
<td>497 505 343 293</td>
<td></td>
</tr>
</tbody>
</table>

1. U, nil meat-and-bonemeal; S, meat-and-bonemeal provided in the ratio 5:1 (silage to meat-and-bonemeal) on a dry-matter basis.
In the previous chapter these attributes were mentioned, especially in relation to shrub legumes, which are well adapted to smallholder situations, especially as a living fence. In Sri Lanka, Chadhokar (1982) observed that *Gliricidia sepium* planted as a 400 m fence around one hectare of land yielded about 1.1 t/yr. dry weight of green leaf if individual plants were harvested at an interval of three months. Since the material contained about 25 per cent protein, a fence of this size would meet the supplementary protein requirements of at least two milking cows during the dry season. A block planting gave 9.2 t/ha of leaf dry matter.

One of the best examples of a self-sufficient, year-round, feeding system for dairy smallholders in a mixed farming area was devised by Gibson (1987, Table 10.7) and his co-workers in northeast Thailand. *Stylosanthes hamata* cv Verano and *Macroptilium atropurpureum* cv Siratro grow well in these soils, and raise soil fertility if fertilised with S and P. Eleven farmers initially undertook to plant 0.64 ha of fertilised legume pasture and acquired two adult milking cows, mostly with a minimum of 50 per cent Friesian heritage.

The composition of the feed supply in the different seasons (Table 10.7) fluctuated in its dependence upon hand feeding. Pastures were heavily used in the main wet season and the early, cool dry season, whilst the rice paddies were mainly grazed in the hot dry season when other grazing was in short supply. Recently harvested sugarcane fields contributed appreciably during the dry season. The volunteer weed component of the cropped areas was a significant feed source.

**Table 10.7. Seasonal feeding regimes of crop products and pastures for dairy production in northeast Thailand (Gibson 1987).**

<table>
<thead>
<tr>
<th>Feed</th>
<th>Season</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cool dry (Nov-Feb)</td>
<td>Hot dry (Mar-Apr)</td>
<td>Early wet (May-July)</td>
<td>Main wet (Aug-Oct)</td>
</tr>
<tr>
<td>Rice bran</td>
<td>36</td>
<td>33</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>Cassava tubers</td>
<td>64</td>
<td>84</td>
<td>27</td>
<td>61</td>
</tr>
<tr>
<td>Cassava tops</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>Sugar-cane tops</td>
<td>58</td>
<td>62</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td><em>Crotalaria juncea</em></td>
<td>28</td>
<td>23</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>24</td>
<td>25</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Rice straw</td>
<td>144</td>
<td>126</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maize stover</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Weeds</td>
<td>4</td>
<td>10</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>361</td>
<td>366</td>
<td>121</td>
<td>177</td>
</tr>
<tr>
<td>Grazing (hours per day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legume</td>
<td>6.6</td>
<td>1.2</td>
<td>4.3</td>
<td>7.3</td>
</tr>
<tr>
<td>Sugarcane fields</td>
<td>1.2</td>
<td>1.5</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Rice paddies</td>
<td>1.2</td>
<td>5.4</td>
<td>3.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>
The main hand-fed roughage source in the dry season was untreated rice straw and sugarcane tops. Rice bran was fed year-round and was produced on the farm or purchased from local mills. Dried cassava chips were grown and processed on the farm as a high energy source, whose use diminished in the early wet season when other feed sources were available. *L. leucocephala* was used in the dry season and *Crotalaria juncea* hay was produced from residual soil moisture in the paddy areas. Minerals were also fed.

In the early phase of this project, milk production (4.4% butter fat) averaged 5.4 l/cow/day with a lactation length of 295 days and calving interval averaged 384 days. Total milk production per farm (two cows) was 3165 l/yr of which 2595 l were sold for US$833 and the balance was mainly fed to calves, who were reared without concentrates.

These practices have been continued successfully, but with some modifications (Udachon and Boonpuckdee 1995). Additions to the list in Table 10.7 may be, corn stover, soybean pod husks, molasses, and * Cajanus cajan*, whilst * Bracharia ruziizensis- Stylosanthes guianensis* cv Graham and *P. maximum* cv TD58 pastures have been planted. The shrub legume offering has been extended to include *Erythrina subumbrans, Desmanthus virgatus* and *Gliricidia sepium*.

A feature of these projects has been the ready adoption by farmers of grazing, rather than of cut-and-carry forage. Where fencing of cropping areas is insecure, tethering gives good results and avoids the immense hand labour involved in cut forage. The return of nutrients to the crop and pasture areas is facilitated by grazing, opportunity for selective grazing to improve diet is maximised, and health problems are lessened. A study at Mueklek, Thailand conducted during the hottest period of the year with 5/8 or 3/4 Holstein Friesian or Red Dane cows showed that day grazing on *P. maximum-S. hamata* pastures gave the same high milk yields attained if the pastures were cut and fed to the cows in the shed (Hongyantarachai et al 1989). Traditional cut-and-carry practices are being re-examined for their possible replacement by grazing, wherever feasible.

**Conclusion**

Sustainability of the forage ecosystem is the primary long-term goal. An investment in improving pastures leads to an environment protected from erosion (Humphreys 1994), to the accumulation of organic carbon which mitigates against global warming, and to the maintenance of crop yields in a mixed farming situation. However these outputs require rational and conservative policies of forage utilisation, which maintain cover on the soil and cycle the nutrients effectively. The deleterious concentration of animal wastes and the transfer of nutrients from adjacent farm lands which are associated with cut-and-carry systems will be mitigated as more smallholders adopt grazing as the norm for dairy animals.

The balance of management objectives is best determined at the individual farm level. The scientist's role is to complement the reservoir of experience and skills developed by smallholders in the husbandry of their animals by providing a hard data base which indicates the probable performance of animals and forages in the many pasture and crop feeding options which are available. Smallholders can then choose from amongst these, the patterns of forage utilisation most suited to their own goals.

**References**

<table>
<thead>
<tr>
<th>Bush and village</th>
<th>0.2</th>
<th>1.7</th>
<th>1.5</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>9.3</td>
<td>9.8</td>
<td>9.2</td>
<td>9.2</td>
</tr>
</tbody>
</table>


A fodder bank of *Leucaena*

Field milking the family cow in Ethiopia.
A fodder bank of *Leucaena* in Cuba.

Donkeys carrying teff hay.

Leucaena eaten to browsing height by cattle at Khon Kaen, Thailand.
Chapter eleven
Feeding strategies for improving milk production
R. Leng

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The basic concepts
An approach to improving nutrition of lactating animals
Background - the use of NPN and bypass protein in ruminant diets
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Efficiency of microbial growth on protein
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Introduction

The basal feed resources for ruminants available in most developing countries in the tropics are crop residues, pasture from infertile land, for example communal land, or agro-industrial by-products. These are low in protein and of low digestibility. Practical strategies for improving milk production of dairy animals on these diets depend on supplementation to optimise both fermentative digestion in the rumen and the efficiency of metabolism of absorbed nutrients.

Specific strategies employ molasses urea multi-nutrient blocks to optimise digestion in the rumen and supplements of bypass protein to improve amino acid supply which in turn optimises the efficiency of
feed utilisation.

The cost of the protein concentrate will often be the primary consideration in many countries. Research must identify local protein sources and develop methods for their protection against rumen degradation. Tree forages, forage from cassava and oil seed meals are likely to increasingly provide these materials.

On the basal feeds generally available in tropical developing countries the major effects of these supplementation feeding strategies may be mainly through increasing the reproductive performance of dairy animals. An increase in reproductive efficiency will increase the total milk production in a country by ensuring that a higher proportion of the dairy animals are lactating at any one time.

The vast majority of small-farmers in developing countries use low input production systems and productivity per cow is relatively low. These smallholder systems vary from ones in which cows or buffalo are fed on crop residues, agro-industrial by-products and roadside grass, to beef cattle grazing tropical pastures that are milked once a day with the calf having access to dam for the other half of each day. In the latter systems the pastures available to these `dual purpose' animals are typical of most tropical grasslands and are relatively low in protein and digestibility.

On these feed resources overall productivity is low, animals reach puberty at a late age (often four years) and intercalving interval is often 18 to 24 months resulting in a small number of dairy animals in a national herd being in milk at any one time. A strategy for improving milk production in these systems has therefore two components. The first is to improve reproductive efficiency of the dairy animals and secondly to improve milk yield and persistency.

The greatest scope for improving a country's milk production is through a strategy which targets improvement of reproductive performance. This cannot be achieved, however, without increasing milk production per animal. Reducing age at first calving from five to three years and intercalving interval from 24 months to 12 months by better feeding management, will at least double the number of animals being milked at one time. In addition, because the same feeding strategy that improves productive performance also increases milk production, the improved production per animal will also be increased.

**Feed resources available to smallholder dairy farmers**

The smallholders of developing countries have limited resources available for feeding to their ruminant livestock. They often do not have the luxury of being able to select the basal diet, they use whatever is available and at no or low cost. The available resources are essentially low digestibility forages such as tropical pastures (both green and mature), straws and other crop residues and agricultural by-products which are generally low in protein. The exception being cassava forage which is a by-product of cassava root production where the latter is sold on the open market.

The major criteria for improvement in production is to optimise the efficiency of utilisation of the available fodder resource and not to attempt to maximise animal production. There is little point in knowing the 'energy' requirements of a cow or buffalo for milk production, whose requirements are to be met from whatever crop residue is available. It is imperative, however, to understand the requirements for supplements that will provide nutrients that will optimise the efficiency of utilisation of that feed resource.

**The basic concepts**

When considering how to optimise the utilisation of the available forages for dairy animals two basic concepts must be applied as follows:
- to make the digestive system of the cow as efficient as possible by ensuring optimum conditions for microbial growth in the rumen
- to optimise production by balancing nutrients so that these are used as efficiently as possible for milk production without jeopardising the reproductive capacity of the cow.

Any further increases in production may be obtained by the use of supplements of protein, starch and lipids to provide nutrients for milk production above that obtained when the efficiency of utilisation of the basal feed has been optimised. These supplements should be processed and must bypass the rumen and become available for digestion in the intestine and in this way provide the nutrients in the correct balances for additional milk production.

The two concepts can be implemented by feeding a combination of non-protein nitrogen (NPN), minerals and bypass protein whereas the third component is a relatively new concept which suggests that milk production, once the efficiency of utilisation of the basal feed resource has been optimised, depends upon feeding in a form that will bypass the rumen nutrients needed for the components of milk. For example, the quantity and balance of glucose (for milk lactose) protein and fat.

### An approach to improving nutrition of lactating animals

In this chapter, research work leading to the application of feeding strategies that emphasise optimal utilisation of available resources for milk production in the tropics are reviewed. The approach taken has been one in which urea molasses blocks (UMB) have been provided to lactating ruminants to allow a slow, continuous intake of nutrients needed to optimise fermentative digestion in the rumen. Bypass protein supplementation is used to optimise the efficiency of use of absorbed nutrients. The development of both these strategies has gone along similar lines, with testing under laboratory conditions being followed by testing on well managed farms and eventual trials under village conditions (Leng and Kunju 1989).

Over the last year all Friesians imported into India, and placed under the care of NDDB (National Dairy Development Board), have been fed according to the strategies proposed (Leng and Kunju 1989). The 300-day lactational yield has been on average 6000 litres.

In addition, several thousand tons of a bypass protein have been fed to cattle and buffalo under village conditions in various climatic zones.

On the basis of this research and the experience gained the largest feed mill in India producing 300 to 600 tons of feed per day (Amul Feed Mill, Anand) commenced the production of a new pelleted feed supplement containing 30 per cent protein and with approximately 75 per cent of the protein in a form likely to bypass the rumen.

### Background - the use of NPN and bypass protein in ruminant diets

Definitions:

- Bypass proteins are defined here as those dietary proteins that pass, intact, from the rumen to the lower digestive tract.
- Digestible bypass protein is that protein of the bypass protein that is enzymatically hydrolysed in, and absorbed as amino acids from, the small intestine.
Overprotected protein is that protein of the bypass protein that is neither fermented in the rumen, nor digested in the small intestine.

Metabolisable protein is the digestible bypass protein plus the digestible protein in the microbes that enter the small intestine.

Fermentable carbohydrates are those parts of the feed carbohydrate that are degraded by microbial action in the rumen to volatile fatty acid (VFA) plus that entering into the microbes that grow with the energy (ATP) released when VFA are produced.

**Protein digestion in ruminants**

In different production systems, ruminants consume many types of carbohydrates, protein and other plant and animal constituents. All digestible carbohydrates are fermented to volatile fatty acids (VFA) plus methane and carbon dioxide by microbial action. Proteins are degraded by microbial enzymes in the rumen to give the same three end-products (that is, VFA, CO$_2$ and CH$_4$) plus ammonia (Figure 11.1). In all cases a proportion of the substrate metabolised by microbes is used for synthesis of the microbes.

The microbial fermentation of soluble protein in the rumen is an unavoidable consequence of the ruminant mode of digestion. In the absence of other forms of N, it ensures a supply of ammonia nitrogen for micro-organisms from which they synthesise the protein in their cells. Under many circumstances it is a wasteful process because high quality proteins are broken down to ammonia, absorbed as such, converted to urea in the liver, which is excreted in the urine. High protein forages such as cassava leaf may contain minimal amounts of bypass protein and as forage it can be consumed in very large amounts by dairy cows.

**Efficiency of microbial growth on protein**

Protein degradation to VFA leads to a relatively low availability of ATP (energy) to rumen microbes and therefore protein that is degraded in the rumen is inefficiently used for the growth of micro-organisms. In comparison with carbohydrate when protein is degraded in the rumen, only half the ATP (the energy currency in microbes) is produced in fermentation of protein relative to the same amount of carbohydrate.

The breakdown of carbohydrate in the presence of adequate ammonia and sulphur and other minerals supplied by, for instance urea molasses blocks, results in more microbial protein being produced than from an equal amount of protein fermented in the rumen. This is shown diagrammatically in Figure 11.1 and indicates that from a highly soluble protein such as leaf protein, less than 10 per cent of the protein in the diet is available to the animal.
It is therefore clear that with readily soluble and fermentable protein; whilst little escapes the rumen if the protein is in high concentrations, the protein to energy ratio in the nutrients arising from the rumen may be decreased.

**Factors that influence the availability of bypass protein**

For a variety of reasons a proportion of the dietary protein passes from the rumen into the small intestine without alteration. On reaching the small intestine this bypass protein is digested by enzyme hydrolysis and absorbed into the body as amino acid.

The conditions under which some dietary protein may escape the rumen for digestion in the lower alimentary tract include:

- when a protein meal has been made highly insoluble by heat treatment
- the protein meal contains tannins (two to four per cent) which bind to make an insoluble tannin-protein complex (Barry 1985) which is not degraded in the rumen but is degraded in the abomasum/small intestine
- chemical treatment has been applied, for example, formaldehyde treatment (Scott 1970)
- when a relatively soluble protein meal is fed in very high quantities and is either in a finely ground form or is rapidly fragmented into small particles which move quickly through the rumen. For example, when clover or lucerne, that do not contain tannins, are fed at levels below 2.5 per cent of liveweight, on a dry matter basis, it is probable that no dietary protein escapes to the lower tract. However, at levels above this, some protein escapes because of the rapid movement of digesta out of the rumen. The amount of bypass protein can be as high as digestible (Dellow and Nolan - unpublished; Nolan and Leng 1989)
- when heat is applied to a mixture of soluble protein and xylose when a modified browning reaction can insolubilize the protein.

**Microbial protein synthesis in the rumen**

Ammonia, peptides, amino acids and amines form the nitrogenous substrate for the synthesis of microbial cells, but ammonia is the most important source of N for the microbes that ferment forages. Ammonia is used by many species of rumen micro-organisms as their sole source of nitrogen for protein synthesis (Leng and Nolan 1984).
This assessment of the role of ammonia in the rumen can be misleading if it is unqualified. Firstly some species of bacteria and protozoa commonly found in the rumen cannot grow or survive unless small quantities of peptides, amino acids or branched chain fatty acids are provided in the diet and are present in low concentration in rumen fluid (Hungate 1966).

A high level of rumen degradable protein in the diet may support high levels of all N-nutrients needed by bacteria and may cause specific populations of microbes to develop in the rumen as compared to diets where urea alone supplies the fermentable N. A deficiency of rumen ammonia results in a low microbial growth rate which may reduce digestibility of fibre and lower intake of feed.

**The requirements for ammonia for microbial activity**

Estimates of the critical level of ammonia in the rumen fluid for efficient digestion has been reported to be between 50 to 200 mg N/l. However, recent studies have shown that when ammonia concentrations fall below about 200 mg N/l, the rumen, micro-organisms are inefficient and are likely to respond to dietary NPN supplements particularly to UMB (Krebs and Leng 1984; Boniface et al 1986; Sudana and Leng 1986; Perdok and Leng 1989). Intake of straw by cattle has been shown to be increased by increasing urea levels in the diet until the level of ammonia reaches 200 mg N/l (Boniface et al 1986; Perdok and Leng 1989).

Recent studies with buffalo fed forage based diets showed that, given a period of access to molasses urea blocks, these animals learn to modify their intake according to the protein content of the basal diet (Table 11.1).

**Can the rumen microbes supply all the protein needs of the ruminant?**

Even when ammonia and other nutrients are supplied the quantities of microbes that leave the rumen in digesta do not supply sufficient protein to meet the needs of productivity in ruminants (i.e. moderate to high growth rates and milk yields). In such a situation the deficiency symptoms indicate an insufficient supply of essential amino acids to the tissue. Under these conditions supplementation with a protein meal (which has a high content of by-pass protein) to supply additional dietary amino acids increases both the level and efficiency of animal production (Preston and Leng 1987).

**Table 11.1. The influence of N content of the basal diet given to lactating buffalo on the intake of a block lick based on molasses urea (Leng and Kunju 1989).**

<table>
<thead>
<tr>
<th>Group number</th>
<th>Diet N content (gN)</th>
<th>Intake of block lick (g/d)</th>
<th>Milk produced FCM (kg/d)</th>
<th>Liveweight changes (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>586</td>
<td>4.3</td>
<td>- 357</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>256</td>
<td>5.7</td>
<td>- 455</td>
</tr>
<tr>
<td>3</td>
<td>83</td>
<td>293</td>
<td>6.3</td>
<td>+ 276</td>
</tr>
<tr>
<td>4</td>
<td>111</td>
<td>173</td>
<td>6.1</td>
<td>+ 89</td>
</tr>
</tbody>
</table>

**Protein (or Amino Acid) requirements of ruminants**

In the past, the protein requirements of ruminants and evaluation of the protein value of feeds for
ruminants have been based on digestible crude protein (N x 6.26). This is now recognised as a misleading concept.

The use of digestible crude protein has arisen largely because it was considered that cattle and sheep could obtain their essential amino acids from microbes produced in the rumen. This in turn led to suggestions that extensive use could be made of non-protein nitrogen in high carbohydrate feeds and that a special role of ruminants could be to convert non protein nitrogen to high quality animal protein. These have now been superseded by new concepts which take into consideration that when amino acid requirements are high, insufficient digestible microbial protein is available from the rumen to meet these needs.

It is now necessary to assess the requirements for N by ruminants in terms of the amount of ammonia (or NPN) and amino acids needed by the rumen microbes, and the amount of digestible bypass protein needed by the animal to augment the total protein (amino acids) available to the animal and to create an efficient metabolism.

The sum of the two sources of digestible protein represent the metabolisable protein. Protein or amino acid requirements relative to energy requirements of ruminants are, however, influenced by a number of factors and cannot be stated with any degree of accuracy. The requirements are influenced by:

- physiological state of the animal
- rate of growth and milk production
- body composition as influenced by previous dietary and health history
- basal feed (particularly fat content)
- proportions of the different amino acids absorbed
- patterns of rumen fermentation, that is, acetate : propionate ratio
- availability of volatile fatty acids
- requirements for glucose, for essential purposes
- environmental heat or cold stress
- the extent of the work load of the animal.
With all these unknowns, the need for bypass protein under conditions pertaining to smallholder cattle can only be assessed in feeding trials aimed at developing response relationships. The utilisation of protein and, therefore its requirements, is well illustrated by the data shown in Figure 11.2.

**Figure 11.2.** The effects of physiological state on the intake and retention of nitrogen in goats fed oats hay/legume (11% crude protein, Helmers 1984).

**Metabolisable protein available to ruminants**

Metabolisable protein available is the sum of digestible dietary bypass protein plus digestible protein from microbes reaching the lower tract.

On most straw based diets the metabolisable protein is mainly of microbial origin, that is, there is no bypass protein in the diet. The amount of protein available therefore depends on the efficiency of microbial growth in the rumen.

This in turn depends on several factors:

- the presence of all the essential nutrients in the balances and amounts needed by the rumen microbes to grow. For example, ammonia, sulphur, phosphorus, trace minerals, amino acids, and peptides
- a source of fermentable dry matter, that is, the feed consumed
- to a small extent the rate of digesta turnover and therefore feed intake. However, this depends on degradability of the feed, type of carbohydrate and the physiological status of the animal
- buffering capacity of the rumen and pH of the rumen fluid which largely depends on diet
- the balance of micro-organisms in the rumen. If supplementation with carbohydrate promotes protozoal population this can actually decrease the protein to energy ratio in the nutrients available in the rumen (Bird and Leng 1985).
As an example of how the balance of microbial protein to VFA energy can be altered in a cow given a straw based diet, the effects of an inefficient rumen (low rumen ammonia supply) and an efficient rumen (optimum rumen ammonia) are shown in Table 11.2. (refer Leng 1982 for calculations).

As Table 11.2 shows, the P:E ratio in the nutrients absorbed is altered according to how efficiently the rumen organisms are digesting the feed or how much bypass protein there is in the diet.

### Table 11.2. The theoretical effect of feeding urea and urea plus bypass protein on the P:E ratio in cattle (values calculated for a bovine consuming four kg of digestible organic matter without or with urea or with urea and 400 g of a bypass protein source).

<table>
<thead>
<tr>
<th>Rumen condition</th>
<th>Microbial protein synthesised (g/d)</th>
<th>Total protein available (g/d)</th>
<th>VFA produced (MJ/d)</th>
<th>P:E ratio (g protein/MJ/VFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deficient in ammonia</td>
<td>500</td>
<td>500</td>
<td>41</td>
<td>12:1</td>
</tr>
<tr>
<td>Sufficient in ammonia</td>
<td>1010</td>
<td>1010</td>
<td>30</td>
<td>34:1</td>
</tr>
<tr>
<td>Ammonia sufficient +10% of the diet as bypass protein</td>
<td>1010</td>
<td>1410</td>
<td>30</td>
<td>47:1</td>
</tr>
</tbody>
</table>

1. No consideration is taken here of the digestibility of the microbial of dietary bypass protein.

### Effect of increasing ammonia concentrations in the rumen of cattle on N deficient diets

In most situations, adding urea to a low protein diet, such as that based on a cereal crop residue, increases intake of the basal diet in addition to improving microbial growth and digestibility (Table 11.3).

The potential effects of providing a UMB to ruminants on low protein forages (which is intended to provide urea and other nutrients) include the following:

- increased digestibility of straw
- increased feed intake
- increased absorption of total nutrients
- increased P:E ratio in the nutrients absorbed.

### Table 11.3. The effect of infusing urea into the rumen of a cow given straw based diets (Campling et al 1962).

<table>
<thead>
<tr>
<th>Diet</th>
<th>Straw DM digestibility (%)</th>
<th>Intake of straw (kg/d)</th>
<th>Theoretical P:E ratio (mg protein/MJ VFA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>39</td>
<td>5.6</td>
<td>12:1</td>
</tr>
<tr>
<td>Straw + 150g urea</td>
<td>47</td>
<td>7.9</td>
<td>34:1</td>
</tr>
</tbody>
</table>
1. Taken from Table 11.1.

The effects of supplementation of bypass protein

Supplementing a diet of crop residues fed to cattle with a bypass protein improves the P:E ratio in the nutrients absorbed (refer Table 11.1 and 11.2). This has a large influence not only on the level of production but on the efficiency of feed utilisation, that is, the amount of feed required per unit of milk production or growth, is lowered. Stated in another way, animals produce less metabolic heat when P:E ratios are well balanced to requirements. This is well illustrated by research shown in Table 11.4 where straw intake has been maintained constant and efficiency of utilisation of the feed is improved in supplementation. In other studies the increased efficiency is not readily discernible as the effect of such supplements is to increase forage intake (Preston and Leng 1987).

Table 11.4. The growth rate of calves (live weight 150 kg) given rice straw and supplemented with an oilseed meal (Saadullah 1984).

<table>
<thead>
<tr>
<th>Daily supplement (g/d)</th>
<th>Straw intake (kg/d)</th>
<th>Liveweight gain (g/d)</th>
<th>Feed conversion ratio (kg feed/kg gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.8</td>
<td>84</td>
<td>46:1</td>
</tr>
<tr>
<td>200</td>
<td>3.8</td>
<td>371</td>
<td>11:1</td>
</tr>
<tr>
<td>400</td>
<td>3.8</td>
<td>373</td>
<td>12:1</td>
</tr>
<tr>
<td>600</td>
<td>3.8</td>
<td>508</td>
<td>9:1</td>
</tr>
</tbody>
</table>

Research illustrating the responses of cattle to urea molasses blocks and bypass protein meal supplementation

Growth studies

Jersey bulls (350 kg live weight) fed rice straw plus a concentrate (low in true protein, that is, about 15 per cent) trebled their rate of weight gain when fed a molasses urea block in conjunction with one kg of this concentrate (Table 11.5).

Table 11.5. The effects of supplying molasses urea blocks to cattle fed rice straw plus one kg 15 per cent concentrate (Kunju 1986).

<table>
<thead>
<tr>
<th></th>
<th>Straw intake (kg/d)</th>
<th>Block intake (g/d)</th>
<th>Live weight change (g/d)</th>
<th>Feed cost/ kg gain (Rupee/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No block</td>
<td>6.4</td>
<td>0</td>
<td>220</td>
<td>9.3</td>
</tr>
<tr>
<td>With block</td>
<td>6.8</td>
<td>530</td>
<td>700</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Studies with lactating cows/buffalo

In ten villages, the average milk sold in the collection centres increased by 0.4 to 1.1 litres per day when
In ten villages, the average milk sold in the collection centres increased by 0.4 to 1.1 litres per day when the farmer made a molasses urea block available to their dairy buffalo (Table 11.6).

The results show the milk or milk fat sold to the local collection centres (Kaira District Co-operative Milk Producers' Union Ltd., Anand, India). Other trials showed that concentrate supplementation could be reduced without loss of milk production when a molasses urea block was given.

### Table 11.6. The observations on response of feeding block licks in villages (Kunju 1986).

<table>
<thead>
<tr>
<th>Village</th>
<th>Milk (kg/d)</th>
<th>Milk fat (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre lick</td>
<td>with lick</td>
</tr>
<tr>
<td>Alwa</td>
<td>4.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Pundadhara</td>
<td>4.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Fulgenamuwada</td>
<td>2.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Hirapura</td>
<td>4.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Bamroli (N)</td>
<td>3.6</td>
<td>4.2</td>
</tr>
<tr>
<td>Dehgam</td>
<td>4.3</td>
<td>4.7</td>
</tr>
</tbody>
</table>

More recently it was demonstrated that feeding a meal high in bypass protein (low in grain) as compared to a cattle feed concentrate based on traditional requirements, increased milk production and live-weight gain without substantially influencing basal feed intake (Table 11.7).

The cattle were each fed 40 kg of green forage daily. The forage consisted of 60 per cent legume (mostly lucerne/cowpea) and 40 per cent non-legume (maize, sorghum/oats). The concentrates for cattle in group one were fed according to NRC recommendations. The cattle in group two were fed a protein concentrate based largely on solvent extracted protein meals demonstrated to have a high bypass protein content. A major point here is that the animals in group one disposed of nutrients equivalent to 20-25 MJ of energy presumably through 'futile cycles of metabolism'. This additional metabolic heat production could have increased body temperature by $16.5^\circ\text{C}$ if the animal had been in an environment where this extra heat could not have been dissipated. The feeding trial was conducted during the cool season but clearly in the hot season feed intake could not have been maintained. Put another way, if the environmental temperature was critical for cattle in group two then the animals in group one would have needed to reduce their feed intake by 20 MJ ME.

### Table 11.7. The effects of replacing balanced concentrates with a high bypass protein pellet on live-weight change and milk yield of Jersey x Kankrej cows (Kurup and Kunju, Personal communication).

<table>
<thead>
<tr>
<th>Group</th>
<th>No. per group</th>
<th>Crude protein in supplement (%)</th>
<th>Intake of supplement (kg/d)</th>
<th>Milk yield (kg/d)</th>
<th>Live weight change (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>18</td>
<td>4.7</td>
<td>8.0</td>
<td>-210</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>30</td>
<td>2.6</td>
<td>8.8</td>
<td>+202</td>
</tr>
</tbody>
</table>

Conclusion drawn from studies in India
The efficiency of feed utilisation is enormously improved if the rumen of the animal has a healthy microbial population adequately supplemented by providing a molasses urea block which often increases the intake of a basal diet. Adding a bypass protein supplement will further improve the efficiency of utilisation of the basal feed resources, but will also allow animals at high environmental temperatures and humidity to maintain feed intake. Conversely, the productivity of lactating animals can be maintained at a lower feed intake, provided the rumen is made efficient and the animal's metabolism is made efficient by supplementing with molasses urea blocks and bypass protein meal respectively.

**Constraints to application of the bypass protein technology**

Even though the application of UMB/bypass technology is highly promising, a few constraints are still to be overcome before it can be widely applied with confidence. Some of these are given below and indicate areas for intensive research.

- The information regarding the degradability of protein in all raw materials used in cattle feed are not yet available and may be quite variable depending on source, manufacturing conditions and presence of other compounds.
- Easy laboratory tests for protein degradability are still not available and there is still some considerable disagreement as to which method provides the best indication of the content of bypass protein in a meal.
- There are insufficient data feeding trials available on milk production per unit of bypass protein under the systems commonly used by small-farmers.
- There are no response relationships for milk production for economic analysis of the feeding of bypass proteins which covers at least two lactations. This is important as bypass protein supplementation on these diets often improves the body condition of cattle and therefore reproductive performance. The second lactation after introduction of these systems may show the greatest economic response.
- Many protein meals are undegradable in the rumen. However, their digestibility in the intestines may be very low. This applies particularly to protein meals with high tannin content. Such protein meals are not good sources of protein to the animal since much of the protein is lost in faeces.
- For the most efficient utilisation of bypass protein for production, the essential amino acid to total N ratio must be high.
- The limits of responses to bypass protein resides in the digestible energy content of the diet and at low digestibility, high level feeding of a bypass protein meal will result in amino acid degradation as an energy supply.

**Practical application of bypass protein in village societies**

**Feeding Friesian cows of high genetic potential for milk production NDDB experience**

Friesian cows of German origin were imported into India as potential mothers for the next generation of bulls for crossbreeding with indigenous cows.

These animals were distributed to (1) NDDB farms with management and accurate recording of milk yield and (2) individual village farmers in cool environments.

The NDDB farms, situated at Anand and Bidaj in Gujarat are in areas with extremely high summer temperatures which often exceed 40_C and may at times exceed 50_C. All animals were fed whatever forage was available and were provided with urea molasses blocks and fed only bypass protein concentrate (30 per cent CP) at 300-500 g/l of milk production. All animals thrived, most are now in their
second lactation and where accurate records have not been kept have produced between 6000-6900 litters of milk per 300-day lactation with peak daily lactations often exceeding 30 litters per day.

The point that has to be emphasised is that these animals were apparently relatively unaffected by the hottest period of the year and maintained milk production at a time when there is usually a marked reduction in milk yield. They were fed the available forage which varied from mixtures of rice straw and green oats/crops through to a mixture of rice straw and tropical grass.

The practical observations support the more controlled research under institutional/ laboratory conditions and indicate a major influence of balancing nutrition on amelioration of heat stress in lactating animals.

**Amelioration of anoestrus in village buffalo/cattle**

A major problem associated with milk production in village societies is that the `non-descript' animals which are by far the majority of dairy animals are often fed the poorest feeds particularly in early life and between lactations. The reason for this is that without the cash flow that comes from milk and with no rapid cash return on their outlay, village people (who always experience cash flow problems) are not prepared to purchase supplements.

In general in developing countries, cattle and buffalo often calve for the first time at four to five years of age and have an intercalving interval of up to two years. Infertility is therefore a major problem.

The improvements in growth rates mediated by the feeding strategies discussed here also suggest that reproductive rate may be similarly improved. A demonstration trial was established to test this hypothesis. Within two village societies cattle and buffalo were selected that had exhibited (over an eight to 12 month period) either infantile genitalia (buffalo heifers) or no ovarian activity in mature cows/buffalo. These animals were provided with molasses urea multi-nutrient blocks over the hot summer months and 90 per cent of these animals came into oestrus after three to four months (Table 11.8). These studies have also been supported by studies of grazing cows supplemented with molasses urea blocks in Africa which have shown a marked decrease in lactational anoestrus period (Table 11.9).

**Table 11.8. The effects of providing molasses urea blocks to cattle and buffalo on reproductive activity** (John, NBBB, personal communication).

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Number of animals coming into oestrus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>before 120 days</td>
</tr>
<tr>
<td>Crossbred cow</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Adult buffalo</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Buffalo heifers</td>
<td>39</td>
<td>28</td>
</tr>
</tbody>
</table>

N.B. The animals were owned by small farmers and had been diagnosed as anoestrous (adult animals) or having infantile genitalia (buffalo heifers) and had been in this condition for eight to 12 months. The farmers were given molasses urea multi-nutrient blocks at no cost. The period covered was the hottest part of the year.
Table 11.9. The effect of providing a molasses urea block (UMB) to grazing cows (Gobe Ranch, Ethiopia) on the length of the post-partum or lactational anoestrous period (ILCA 1988)

<table>
<thead>
<tr>
<th></th>
<th>Post-partum anoestrous period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No supplement</td>
</tr>
<tr>
<td>Suckling calves</td>
<td>132</td>
</tr>
<tr>
<td>Restricted suckling</td>
<td>114</td>
</tr>
</tbody>
</table>

The implications of these discoveries for improving milk production is extremely large. Decreased age at first calving together with decreased intercalving interval may increase the total number of animals lactating at any one time by two or even threefold, this in turn will increase milk production from the national herd by the same increase.

**Treatment of crop residues to improve digestibility**

The treatment of crop residues with alkalis to improve digestibility is a well-researched and established technique. Feeding treated straw as compared to untreated straw considerably improves ruminant productivity (Sundstol and Owen 1984).

Simple techniques based on ensiling the wet straw (50% moisture) with three to four per cent urea, are well established and could be applied under village conditions. However, these techniques are only being accepted slowly or are unacceptable to smallholders for a variety of reasons which vary from country to country and within districts in the same country.

The main constraints to implementing straw treatment as a means of improving milk production in smallholder dairy systems are economic, sociological and logistic.

**Economic considerations**

Small-farmers invariably have a cash flow problem and purchase of urea is restricted generally for crop production. Often plastic covers for the straw are costly and impractical. In addition, the returns for the use of urea on a rice crop must be offset against the income from milk.

**Sociological considerations**

Often the most appropriate time for treatment of crop residues is at harvest time, when most of the family are involved in long hours of work and have no time to treat straw.

The availability of water is often a constraint. In most countries this would be carried in urns by the women from a distant source. These wives and daughters of smallholders generally have very full working days. Often for security or convenience purposes straw is stored in or close to the residence of the family and the smell of ammonia is highly unacceptable and may lead to eye disorders particularly in children. Finally, wet straw is much more difficult to store, preserve and feed to the cattle.

For straw treatment to be successfully accepted by smallholders in developing countries the methods must be made easy, low cost and must have low labour inputs. It seems that for the foreseeable future straw treatment is unlikely to develop as a national strategy, but will be used by the larger farmers particularly...
those that can afford to buy labour.

**Research needs**

For the implementation of the new feeding system, more feeding trials need to be carried out in which response relationships of milk production/weight change can be correlated with level of bypass protein feeding. However, some of this can be left to individual farmers who can be instructed to slowly increase the level of protein meal until they are satisfied with the response. They will automatically take the most economic option and the important point to stress is that farmers must have access to the supplements.

The influence of these feeding strategies on reproductive performance needs further research as it is likely to have the greatest effect within a country.

The feed processing technology should be modified in view of the new system with a view to increasing, in processing, the bypass protein content of a pelleted feed. A suitable feed formula based on the nutrient supply, processability and economics of feeding needs to be developed, for use with the important basal feeds available to smallholders.

There is a wide gap today in this technology between the research nutritionists who use only single ingredients or a combination of two or three protein meals and the practical feed manufacturer who uses a variety of feeds compounded on least-cost basis.

Since many developing countries have large quantities of protein meals in the country then technology development to ensure its efficient utilisation should be a matter of priority. In countries where the oilseed meals are unavailable, the potential of forage trees containing tannins, or the treatment of forage trees containing tannins, or the treatment of forage tree leaves to protect the protein need to be developed.

The challenge for the scientist in many developing countries is to how best combine in a diet for dairy animals the available green forage, crop residues and agri-industrial by-products with the available protein resources and molasses urea block to optimise milk production. This is likely to be the primary economic constraint. It is therefore necessary to develop new protein resources, for example, aquatic plants and tree crops, and to find ways and means of protecting the protein from degradation in the rumen whilst remaining of high digestibility.

**Increasing milk production following optimisation of the efficiency of utilisation of the basal feed resource**

The ‘Greenhouse effect’, that is, the warming of the earth's atmosphere because of increased content of carbon dioxide and methane, will in the future require a reduction in production of these gases. Methane produced by ruminants probably contributes about 25 per cent of the increase in global methane concentration in the atmosphere, which is one per cent per year at present. This source of methane can be reduced by decreasing the number of ruminants in the world. This will necessitate a move to increase production per animal to maintain and increase this source of human food. This increase per animal will need to be made within the constraints of the available feed resources.

Milk is essentially, water, lactose, protein and fat. To boost production of milk from animals fed available forages above that stimulated by the optimum level of bypass protein plus urea molasses blocks, it will be necessary to supplement well balanced mixtures of amino acids (from bypass protein) and lipids (as unreactive LCFA combined with calcium to form soaps) and bypass starch.
The role of dietary fat in the nutrition of ruminants has traditionally been looked upon as a means of increasing the energy intake of ruminants without a proportional increase in the quantity of feed consumed. Milligan (1971) made a strong case for inclusion of fats in ruminant diets on the basis of the energetic efficiency of incorporation of dietary long chain fatty acids (LCFA) into tissue LCFA of fattening animals. Kronfeld (1976, 1982) proposed that an optimal balance between aminogenic, glucogenic as well as lipogenic nutrients is required for maximal efficiency of milk production and prevention of ketosis in highly productive dairy cows. Theoretically, this should be achieved when, amongst others, exogenous LCFA contribute 16 per cent of the total ME intake (Kronfeld 1976). Similar levels of LCFA inclusion in the diet of lactating cows, was determined to result in an optimal efficiency of nutrient utilisation for milk production by Brumby et al (1978).

Very little information is available, however, on the influence of dietary LCFA on the efficiency of nutrient utilisation by growing and lactating ruminants, especially when they are fed roughage-based diets.

Although results reported in the literature are highly variable, generally it is believed that the inclusion of more than four to six per cent fat in the diet will result in a reduced digestibility of fibre in the rumen and sometimes a reduced DMI (Kronfeld 1982; Moore et al 1986), unless these lipids are offered in a form which makes them relatively inert in the rumen.

Calcium salts of LCFA (Ca-LCFA) are such a source of ruminally inert LCFA (Palmquist and Jenkins 1982; Jenkins and Palmquist 1984) and have been shown to increase milk production by dairy cows when used as a feed supplement (Palmquist 1984). Interactive effects of dietary LCFA with nutrients other than fibre have received little attention.

An interaction between dietary LCFA and protein meals has been found and on low protein diets, the benefits of dietary fat are only apparent when a bypass protein is fed (van Houtert and Leng 1986).

The quantitative importance of these possible nutrient interactions is unknown in dairy animals fed forage based diets but since the nutrients in milk arise from long chain fatty acids, amino acids and glucose, research is now being aimed at developing a supplement which provides these, directly to the animal.

References


Sudana I.B. and Leng R.A. 1986. Effects of supplementing a wheat straw diet with urea or a urea molasses block and/or cottonseed meal on intake and liveweight change of lambs. *Animal Feed Science and Technology* 16:25.


Chapter twelve
Dairy management and animal health
S. Aiumlamai

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Newborn calf: First three days
Calves from three days to one month
One month of age to weaning (3–4 months)
Calves 4–12 months of age
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Housing and environmental control in the tropics
Dairy cattle diseases
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Introduction

In tropical areas, disease compounds with the temperature and humidity to cause stress on animals. Herd management practices in cow handling, nutrition, milking procedures, sanitation and housing play major roles in predisposing the individual animal as well as herds to diseases. Decisions of herd managers or cattle owners are the main influence for reducing health problems. Thus, herd management practices combined with a veterinary program can be most effective in optimising production and profitability through prevention of diseases.

Control of diseases which are transmissible from cattle to humans, spread through vectors or wild animals, or epizootic diseases is normally the responsibility of governments and international agencies. The control of other diseases and parasites is the responsibility of herd owners. Vaccination programs against endemic diseases are usually required by national laws which should strictly followed by dairy farmers, co-operative and dairy organisations. Many countries in the tropical zone and warm climate zone have specific policies for the control of diseases. In some dairy regions, the dairy co-operatives or dairy farming promotion organisations provide veterinary services for their membership on a (partial) cost recovery basis. Not withstanding, governments responsibilities, allocated resources are limited in terms of both staff and therapeutic drugs. There are seldom sufficient numbers of veterinarians working in the
dairy regions. In most dairy areas therefore para-veterinarians or veterinary-assistants are an important support for regional veterinarians. Coupled with this deficiency is the continued expansion of dairy farming, particularly in Asia.

Dairy farm management should be sophisticated, particularly in the tropics with the added environmental stresses. However, smallholder and small dairy co-operatives often lack the necessary management skills. Co-operatives are not usually strong enough to manage proper health control and services for members. Dairy farming itself requires basic education and training. Time is required for dairy farmers as well as the veterinarian assistants and veterinary practitioners to gain experience.

In tropical countries, public investment in promoting livestock development will go to support health services, disease control and vaccination production and programs. Government budgets leave little for research and monitoring animal performance on farms for gathering data to serve as technical inputs to the national trend analyses. National Herd Improvement records are the major tools for assisting high production efficiency including sound health as well as for providing data for genetic improvement programs. Some countries have started national milk recording schemes for dairy herds which assist genetic improvement programmes. However, records from smallholders are seldom comparable to those of western dairy nations.

In the tropics, climatic and environmental stress, particularly heat stress, could affect animal productivity (Matthewman 1993). Signs of stress include loss of appetite, reduced daily milk yield, increased temperature, high respiratory rate, tongue protruding, open month breathing, inability to lie down, and a preference for remaining in cool waters, for example, swamps. The owner should be able to recognise the signs and try to adjust the environment and housing to reduce stress and let the animal be as comfortable as possible. Healthy animals are alert, active, have bright eyes, with no discharge, smooth and shiny skin, breathe and urinate regularly, and their tail moves to drive away flies.

An important aid for farm management is the keeping of records of all animals and events relating to animals throughout their lives. In some countries, record keeping is provided, supported and designed by the government or dairy co-operatives. Records should be kept as individual cow cards at farms or at the dairy health service or artificial insemination service centre. Some co-operatives in Thailand have moved to computer storage of data. The main purpose of the records is for dairy herd management, breeding and progeny testing. Records of insemination, birth date, sire, dam, calving date, vaccination date, health problems, treatment, milk yield and feeding can help farmers to predict future or preventative needs for health care. They also provide beneficial and relevant information for veterinarians to make correct diagnoses. Therefore, it is best to have well organised records kept for each animal, with the forms designed to allow for easy interpretation. Smallholders do not seem to pay sufficient attention to keeping good records. The dairy herd improvement program is a beneficial tool for farm management but the procedures tend to be costly and need a lot of technicians to access smallholders in the tropics. It also takes a great deal of effort to educate farmers to use and keep using data. This may relate to ambitious programs being copied from western dairy nations rather than beginning with simple systems in individual milk collection areas where reliance on government services is less than for a national database.

General dairy herd management and health programs in the tropics are similar to those of herds in other warm climates (McDowell 1994) and, to a lesser extent, cool climates (Ames 1995; Behlow and Ensminger 1993). However, tropical climates add stresses which compound health problems and increase the incidence of disease. Viral vaccines, which would ideally be used in national programs are imported spasmodically, creating a continuous disease threat which smallholders must integrate into their management systems. The minimisation of stress can be accomplished through good housing and care, and thereby reduce the risk of disease. Likewise limiting the percentage of *Bos taurus* blood in
crossbreeds of smallholders reduces the need for sophisticated management and facilities.

Practical health care

Health care of dairy cattle can be best described by age and state of the animal as set out in the following sections.

Newborn calf: First three days

- The newborn calf needs to be cleaned with dry a towel or clean and dry hay. This will stimulate respiration and blood circulation.
- Remove slime from the nose and mouth to assist breathing and holding up the rear legs of the calf, let the head hang down to release any water in the lungs, mouth or nose.
- If the navel is too long, cut it and leave two to three inches from the stalk then dip the navel in tincture of iodine to prevent local infection. This procedure is important for prevention of navel-ill (omphalitis) and helps the umbilicus heal quickly.
- Feed the calf with colostrum within one to two hours after birth. The optimum time for absorption of antibodies through calf’s small intestine is in the first six to eight hours. Colostrum should provide the calf with 10 to 15 per cent of its body weight. It is essential that the calf receives enough colostrum during the first 12 to 24 hours to prevent early infection. The colostrum is high in nutritive value; it contains antibodies IgG and IgM from the cow’s immune system which form passive resistance to many infections.
- In general, removal of the calf from the dam should occur after calving to the isolate pen which should be dry and clean. Straw for bedding must be clean and dry and should be changed regularly.

Calves from three days to one month

- Feeding with whole milk is expensive so milk replacer is used for routine feeding, which is twice a day. Bucket feeding is commonly used; it should be cleaned well between uses to avoid digestive disorders due to poor hygiene.
- Train the calf to take concentrate and roughage at about one week of age. Solid food stimulates rumen development. In the pen, clean water must be available at all times.
- Calves are numbered using an ear-tag or tattoo. Removal of extra-teats could be done in the first weeks.
- Common health problems during this period are omphalitis (navel-ill), diarrhea (scours), respiratory infection (pneumonia) and arthritis.

One month of age to weaning (3–4 months)

- Calves should be dehorned at one to two months of age.
- All female calves should be vaccinated against brucellosis (S19) at three to eight months of age.
- Weaning should take place at about three to four months of age or when the calf is able to eat roughage and concentrate of more than one kilogram per day or at calf body weight between 80 to 90 kg (depending on the breed).
- De-worm the calf against internal parasites such as roundworm, tapeworm and flukes. Also, eliminate external parasites such as ticks by spraying.
- In this period problems to be aware of, are parasites, bloat and arthritis.
Calves 4–12 months of age

- Vaccinate against FMD (foot-and-mouth disease), hemorrhagic septicemia and/or anthrax every six months.
- De-worm against internal parasites such as roundworm, tapeworm, flukes and also eliminate external parasites such as ticks, by spraying.
- In this period problems to be aware of include parasites, tick fever, pneumonia, diarrhoea, bloat and arthritis.

Heifers 12–18 months of age

- Record the growth rate for which should not be less than 270 kg in crossbred or 300 kg in pure-bred cattle at first service.
- Take blood for brucellosis and do tuberculosis test.
- Vaccinate against FMD (foot-and-mouth disease) and hemorrhagic septicemia every six months.
- De-worming should be carried out every six months.
- Heat detection should be carried out to determine the right time for artificial insemination and use of selected semen in accordance with the breeding plan of the region or farms.
- Heifers requiring repeated insemination (more than three times) need to be checked by a veterinarian.
- Heifers over 18 months old and/or weighing more than 270 kg which have not shown signs of oestrus need to be checked by a veterinarian.
- Pregnancy diagnosis should be done on each animal at 45 to 60 days after the last insemination.
- Common health problems that occur during this age are, three-day sickness (ephemeral fever), tick fever, and other infectious diseases and parasites.

Pregnant heifers – prepartum (24–36 months)

- Feed with good quality roughage and give concentrate as a supplement to pregnant heifers in poor condition.
- Mineral supplement can be used for pregnant heifers to prevent metabolic diseases such as milk fever.
- Vaccinate against FMD, hemorrhagic septicemia and other diseases as a vaccination program in the dairy region.
- De-worming for external and internal parasites should be carried out routinely. Signs that the cow is approaching parturition are that it becomes uneasy and separates from the herd. Signs of calving include enlargement of the udder and belly, and discharge from the vulva.
- In this period, one must be alert for heifers mastitis (mastitis before calving) and abortion.

At parturition

- The owner needs to prepare the calving area which should be clean, dry, quiet and isolated to keep the prepartum cow close for the owner to notice and provide help if the cow shows signs of difficulty during the birth.
- Signs of calving include enlargement of the vulva, distention of the teats and udder, loss of ligaments at the side of the tail-head, and restlessness. Other indicators are a marked increase in the amount of mucous, cervical seal liquefaction and increasing frequency of abdominal and uterine contractions.
- If delivery is determined to take longer than 24 hours and the allantoic sac has not protruded, the cow will require assistance from a veterinarian.
● If there has been no expulsion of the fetus or any contractions for more than two hours after the rupture of the allantoic sac, veterinary assistance will be required.
● During this period, there is the possibility of milk fever, uterine prolapse, or downer cow occurring.

After calving: seven days postpartum

● Natural expulsion of the fetal membrane should occur three to eight hours after calving or within 12 hours. If the fetal membrane is retained over 12 hours, the cow will require assistance from a veterinarian.
● Milk colostrum and feed to calf as soon as possible (within six hours).
● Remove the fetal membrane from the calving area or pen floor, clean the pen and the rearing area of the dam to reduce risk of infection by flies.
● Feed the cow with good quality and quantity of food which is palatable because in this period the cow has less appetite and may remain stressed from delivery.
● During this period, there is the possibility of retained placenta, metritis, milk fever, uterine prolapse and mastitis.

Milking

● Be aware of weight loss after parturition which is a sign of insufficient energy in the diet.
● Try to group cows for feeding and management according to their milk production.
● One month after parturition check the reproductive tract for uterine involution, metritis and ovarian functions.
● The cow should show signs of oestrus within 60 days postpartum; cows requiring more than three inseminations need to be checked by a veterinarian.
● During this period, there are risks from mastitis, metritis, abomassal displacement, acidosis and ketosis.

Dry period

● Check for pregnancy diagnosis once again before allowing the cow to dry off.
● Drying-off should allow at least two months before the coming parturition to let the cow rest and prepare to calve. Prevention of mastitis during the dry period and after calving is important.
● Maintaining the routine vaccination program.
● Treat for internal and external parasites.
● Hoof trimming can be done during this period.
● Maintaining good feed management during the dry period. Dairy health care management can be followed as a cycle as shown in Figure 12.1.

Replacement heifers

Firstly, the health record of the purchased animals needs to be correct. Information on vaccinations and health problems as well as breeding certificates and individual cards from former owners are valuable. Quarantine may be necessary before new animals can enter a farm. Shipping animals creates stress, so cattle should be handled as gently as possible when loading or unloading. Shipment should be done in the shortest possible period of time and during the coolest part of the day. If there is any doubt about the health of the cattle their temperature should be taken before loading. It is more economical to treat feverish animals and delay shipment than to risk stress-induced illness or death.
Culling

Smallholders like to retain all cows, even those with low milk production or which never conceive. Good herd management requires the culling of unproductive animals from the herd and replacement with improved stock. Unwillingness of some smallholders to cull according to good practice may be related to sentiment and distraction by other agricultural enterprises which limits attention to the production levels of individual cows. Serious dairy farmers will follow the practices of culling.

Male calves are not economical to keep, and farmers will sell them cheaply or cull them from stock as soon as possible. Farmers prefer to keep only female calves as future replacement cows. Beef farming using dairy male calves is limited compared to raising local multipurpose cattle; however, in countries where markets develop for quality local beef and local customs allow killing of cattle, a potential smallholder industry exists.

Housing and environmental control in the tropics

It is very important to provide appropriate conditions for rearing dairy cows in the tropics by reducing the extreme effects of climate such as heat, and moisture. Good housing and layout of the farm can reduce stress. Environmental control improves milk production by reducing stress and disease hazards, also making management easier. In conjunction with a good herd health management program, housing can be a main determinant of productivity.

Housing location, design and construction should follow the principles below:

**Location.** Factors which need to be considered in choosing land for farming are fertile land, no evidence of flooding during the wet season, convenient for transportation, proximity to the milk collecting centre, access to supplies for farming, clean and sufficient water all year, and distance from factories or other farms which may release bad odours or lead to pathogenic infections.

**Ventilation.** Housing should be on high ground or in clearings which allow for better ventilation. The roof should be high enough to release heat, moisture and pollutants. The slope of the roof can provide protection from the effects of sun and rain, and breezes can blow through the stable to keep the house dry and cool.

**Direction of the housing.** A gable roof is recommend for housing and the front of the house should face east-west. The longitudinal of the stable should be parallel to the sun. Placing the stable in this direction will protect it from morning and afternoon sun and rain.

**Sanitation.** The stable or milking area should be designed to be convenient for working, milking, feeding and ease of cleaning.

**Roof.** Good roofing provides protection from the hot climate by allowing movement of the air through the roof and increasing ventilation. The roof or shelters need to be well designed to protect animals from rain and prevent cold stress and reduce heat loss during the night. Thatched roofing is used a lot in the tropics as it is cheap and can provide good protection if well designed. Tiles are preferred where they are affordable.

**Walls.** Housing in the tropics is mostly open-sided to allow maximum ventilation and air movement through the shelter to keep the inside environment similar to the air temperature.

**Floor.** Concrete or easily washable material is required for the floor. It should be designed for good
drainage and meet hygiene criteria. The floor should be sloping and have channels which allow urine to run away and faeces and urine to be frequently drained or removed. Houses should be disinfected regularly to reduce pathogenic micro-organisms and reduce the number of flies.

**Milking shed.** Smallholder housing should be designed for keeping concentrate in the milking area. Farmers should use feed concentrate and/or roughage before or during milking in the milking stable. The area for keeping milking equipment should be shaded.

**Foot bath.** Designing an area for dipping feet before entering the milk stable and/or after milking can reduce footrot. Copper sulphate (three to five per cent) mixed with clean water serves as a suitable disinfectant.

To reduce heat stress situations, farmers should have well designed housing with good air movement and shade. Handling animals during periods of high temperatures and humidity, should be avoided and provide good quality, cool drinking water provided at all times. An area as pasture for cattle to exercise, aids health care. Resting or exercises areas should be close to the milking shed. Calf housing follows similar principles with raised slatted floors giving good ventilation. Calves should be housed separately to avoid sucking each other, swallowing hair leading to hair balls then cause bloat in calves and ensures that they receive their ration of food.

**Dairy cattle diseases**

Tuberculosis needs to be tested for in individual dairy cattle. The tuberculin test on the caudal fold is a practical method used world-wide. The brucellosis test, by individual serum, is also carried out in endemic areas. Control of internal parasites should be conducted every six months, or during the drying-off period in the cow. Control of tick borne disease is by routine controlling of the vectors or external parasites, dipping or spraying by acaricide to eliminate the ticks on the cattle’s body at three week intervals.

Vaccination programs commonly used in the tropics are:

- Brucellosis (S19) – females should be inoculated during three to eight months of age once in their lifetime.
- Foot and mouth disease type A, O, Asia-1 depending on the region, should ideally be vaccinated every six months.
- Hemorrhagic septicemia should be vaccinated every 6 months.
- Anthrax vaccine should be administered every six months for five years in endemic areas.

Diseases commonly found in dairy cattle include bacterial infections such as anthrax, blackleg, brucellosis, dermatitis (ringworm), diarrhoea, Hemorrhagic septicemia, infectious foot rot, infectious keratoconjunctivitis (pink eye), leptospirosis, mastitis, melioidosis, metritis, paratuberculosis, pneumonia and tuberculosis. Common viral infections are bovine ephemeral fever, bovine viral diarrhoea (BVD), bluetongue, foot and mouth disease, Infectious bovine rhinotracheitis (IBR), bovine leukosis, pseudorabies, rabies and warts. Protozoal infections commonly found are, blood parasites as anaplasmosis (Anaplasma marginale, Anaplasma centrale), babesiosis (Babesia bovis, Babesia bigemina), theileriosis (Theileria spp), and trypanosomiasis.

Major internal parasites are rumen fluke (paramphistomosis), liver fluke (Fasiola gigantica), schistosomosis (Schistosoma spinale), strongyloidosis (Strongyloides papillosus), moniezia, trichuris, ascarosis (toxocara vitulorum), gastro-intestinal nematodes (Mecistocirrus spp, Oesophagostomum spp, Bunostomum spp, Haemonchus spp), and coccidial diarrhoea (Eimeria. Cryptosporidium). Maior
ectoparasites are ticks causing tick fever, mange (Demodex bovis, Chorioptes spp) and flies (Chrysomyia bezzina). Others diseases which have been reported are acidosis, bloat, milk fever, ketosis, dystocia, retention of placenta, vaginal prolapse, hard ware disease or traumatic reticuloperitonitis, downer cow syndrome, nutrient deficiency, vitamin B1 deficiency, laminitis and urea toxicity.

An example of dairy health care is available from the incidence of health services provided by the DPO of Thailand in 1994. Of the 30,502 times a service was provided, the majority related to reproductive disorders (Table 12.1).

**Table 12.1. Dairy health service record from the Dairy Farming Promotion Organisation of Thailand (DPO) in 1995.**

<table>
<thead>
<tr>
<th>Service Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive system services</td>
<td>31.4%</td>
</tr>
<tr>
<td>Including, metritis 21.6%, retained placenta 4.4%, infertility or repeated breeder 3.1%. Others include, dystocia, cystic ovaries, uterine prolapse, abortion, cesarean section, uterine torsion, each being less than 1%.</td>
<td></td>
</tr>
<tr>
<td>Mammary system services 8.2%</td>
<td></td>
</tr>
<tr>
<td>Clinical mastitis 7.7%, the others are wound, abscess and blind teats.</td>
<td></td>
</tr>
<tr>
<td>Blood parasites services 2.9%</td>
<td></td>
</tr>
<tr>
<td>Anaplasmosis, babesiosis and trypanosomiasis.</td>
<td></td>
</tr>
<tr>
<td>Other illnesses 51.4%</td>
<td></td>
</tr>
<tr>
<td>Service de-worming 8.2%, vitamins and supportives 9.0%, three-day sickness 5.3%, keratoconjunctivitis 2.5%. Others include, milk fever, laminitis, respiratory infection, bloat, ketosis, wart, leptospirosis, traumatic reticulitis, abomasal displace, each being less than 1%.</td>
<td></td>
</tr>
<tr>
<td>Illness in calf 6.2%</td>
<td></td>
</tr>
<tr>
<td>Calf scours (diarrhoea) 2.1%, respiratory infection 1.7%. Others include, omphalitis, emaciation, bloat, arthritis and abnormality at birth, each being less than 1%.</td>
<td></td>
</tr>
<tr>
<td>Positive test for brucellosis was 0.1% and for tuberculosis 0.05%</td>
<td></td>
</tr>
<tr>
<td>NB These were tested in 1,348 farms of 18,253 head of cattle in 1994.</td>
<td></td>
</tr>
</tbody>
</table>

Good health care, herd management and disease control programmes impact on dairy cow productivity. Nutrition is also critical and, in common with health, should be viewed as a major component of herd management. In the case of sick animals farmers need to detect them quickly, and isolate them from the rest of the herd to begin treatment. A sharp eye for possible problems within the herd will make early diagnosis and treatment an effective management tool. If an animal goes off its feed, decreases milk production, has a cough, diarrhoea, lameness, or an unusual discharge, further diagnoses should be made by a veterinarian. Sick cows should be isolated from healthy ones to avoid the spread of infectious
diseases. Examination and diagnosis should be considered for the entire herd not only individual animals by following the steps shown in Figure 12.2. The details of diseases mentioned above in etiology, pathogenesis, clinical findings, diagnosis, prevention, control and treatment have been well described by Blood and Radostits (1990) and Behlow and Ensminger (1993).

Conclusion

The operation of a dairy farm for maximum profit includes good feeding, breeding, care and management, as well as, good record keeping and a dairy health program. The objectives of the health program are to prevent the introduction or occurrence of disease and to control the spread of infectious diseases and parasites (May 1981). Most of the diseases or hazards in the tropics are quite similar in the cool or warm climate zones. Government regulation, to eradicate epidemic diseases in dairy cattle usually depend on specific experience in each country. The diseases transmitted from dairy cattle and dairy products to humans, play an important role, legally, and are the responsibility of government and international agencies. Dairy co-operatives must consider health care, particularly diseases transmitted from cattle to humans and influence on milk spoilage. Veterinary services and dairy extension staff should emphasise continuing education for farmers in the areas of farm management and disease control as well as providing effective services. However, in the final analysis, it is the smallholder who must understand the reasons for good management practices and the links between nutrition, housing and health.

References


Figure 12.2. Examination of a herd for diagnoses (Blood and Radostits 1990).
Raising crossbred cows in the northeast of Thailand. Rice straw is the main roughage source for dairy cattle in the tropics, particularly in the dry season.

A practical calf rearing and housing on a smallholder dairy farms.
A shower bath before milking is a popular traditional way of handling cows in the tropics. The main purposes are to clean animals before milking and to reduce heat stress.

Corn stalks left after harvesting are an important source of roughage for dairy cattle. Farmers in some areas could use this local by-product.
A veterinarian giving treatment to a sick cow as a routine service. However, in general there are too few vets in the field and commonly para-veterinarians are the ones who provide services or make the first diagnosis.

Housing of dairy cattle in the tropics.
Chapter thirteen
Management of reproduction
O. Perera

The importance of reproduction in dairy production
Reproductive events
Puberty
Sexual cycles and mating
Pregnancy and parturition
The postpartum period
Reproductive efficiency
Effects of genotype
Effects of nutrition and environment
Effects of management practices
Effects of breeding management
Infertility and sterility
Delayed puberty
Anoestrus
Repeat breeding
Infectious causes
Accidents and miscellaneous causes
Male fertility, natural breeding and artificial insemination
Male fertility
Natural breeding
Artificial insemination (AI)
Modern reproductive technologies and potential applications
Oestrus synchronisation
Embryo transfer (ET)
Hormone assay
Ultrasoundic imaging
Management of reproduction for optimum efficiency
Genotypes, records and general management
Heat detection and mating
Care of pregnant and parturient animals
The postpartum period
References and suggested reading

The importance of reproduction in dairy production

An important prerequisite for the sustainability of a dairy production system is that cows must have efficient reproductive performance. This is essential for the production of the main commodity of interest,
milk, as well as to provide replacement animals. Over and above this, and particularly in smallholder systems, the animals must also provide other outputs which will directly or indirectly result in economic benefits to the farmer. These include, in different combinations depending on the system, meat, draught power, fuel and fertiliser. Since the continued generation of these outputs all rely on the production of offspring, no dairy production system is sustainable without an acceptable level of reproduction.

From the viewpoint of reproduction, the main factors which contribute to economic losses are delayed puberty, long calving intervals, short productive life (due to culling for infertility or sterility) and high calf mortality.

The relative importance of reproductive management in the efficiency of dairy production systems varies widely. It may vary according to the environment, genotypes, scale of inputs and outputs, managerial skills of the farmers and economic as well as sociological considerations. Also, the reproductive functions and normal fertility parameters of tropical cattle and buffalo have important differences depending on the genotype and its interaction with the environment. Thus, due to the large number of genotypes used in smallholder dairy production in the different tropical countries of the world, and the multitude of environments and production systems under which they are reared, generalizations are difficult. From a practical point of view, however, maintaining an optimum level of reproductive efficiency is largely a matter of matching the genotypes to the available resources, and of appropriate management strategies to allow the animals to express their full reproductive potential.

This Chapter discusses aspects of the reproductive biology and fertility parameters of, and provides practical guidelines for management of dairy animals for optimum reproductive efficiency for, the commonly used types of tropical dairy cattle (Bos indicus or zebu and their crosses with Bos taurus) and buffalo (Bubalus bubalis; river types and their crosses with the swamp type).

Reproductive events

During the lifetime of an individual female, higher reproductive efficiency yields more calves for use as replacements or for sale in the herd, as well as more lactations and therefore more milk. These considerations become more important as rearing conditions become more intensive, where expenses for labour and feed have to be compensated for by higher income.

In order to fulfill its role as an economically useful animal to its owner, dairy females must perform the following functions:

- grow rapidly from birth until puberty
- attain puberty at an early age
- conceive readily to a fertile mating
- produce a viable calf
- produce adequate milk for the calf and extra for sale
- return to oestrus early during the postpartum period and conceive again
- continue producing calves and milk at regular intervals till the end of its productive life.

The ability of an animal to meet these requirements will depend on many factors as outlined below.

Puberty

In the female ruminant, puberty is defined as the first behavioural oestrus accompanied by ovulation and development of a normal corpus luteum (CL) in the ovary. This is determined by several factors, which
are endogenous, for example, genotype, growth and body weight, as well as exogenous, for example, year or season of birth, rainfall, nutrition, thermal environment, photoperiod, and rearing method and diseases. Generally, cattle and buffalo heifers attain puberty when they reach 55 to 60 per cent of their adult body weight. However, the age at which they attain puberty can be highly variable, ranging from 12 to 40 months in cattle and 18 to 46 months in buffalo. Thus growth rate and body weight are more important determinants of puberty than age. Under optimum conditions, taurine cattle and their crosses attain puberty earlier than zebu cattle, river buffalo and their crosses earlier than swamp buffalo. However, zebu cattle and buffalo generally have a longer productive life than taurine cattle and some of the disadvantages of late puberty are compensated for by their longevity.

The main factors which influence the age of attainment of puberty are the genotype, nutrition, management, thermal environment, year or season of birth, parasites and diseases.

**Sexual cycles and mating**

Adult non-pregnant heifers and cows normally undergo regular oestrous cycles, which have a mean duration of 21 days (Table 13.1). The oestrous cycle has four stages: pro-oestrus, oestrus, met-oestrus and di-oestrus.

During pro-oestrus, under the influence of the two pituitary hormones, Follicular Stimulating Hormone (FSH) and Lutenizing Hormone (LH), one follicle (rarely two) from a group of growing follicles in the ovary continues to grow and mature and secrete estrogens. Estrogens act on the brain of the cow and cause the behavioral changes characteristic of oestrus or heat. Simultaneously, effects on the reproductive tract cause changes such as swelling of the vulva, hyperemia of the vagina, secretion of cervical mucus and increase in uterine tone. The high estrogen levels trigger a large release of LH which causes ovulation after the end of the heat period. After ovulation the remnants of the follicle are transformed into the CL which secretes progesterone and prepares the reproductive tract for pregnancy. Some discharge of blood, termed met-oestrus bleeding, can be seen from the vagina in most heifers and about 60 per cent of cows. This is in no way related to whether conception occurred at the preceding ovulation.

**Table 13.1. Duration and timings (mean and range in parentheses) of events associated with the oestrus cycle.**

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th>Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of oestrus cycle (d)</td>
<td>21 (17-25)</td>
<td>21 (17-25)</td>
</tr>
<tr>
<td>Duration of oestrus (h)</td>
<td>18 (6-30)</td>
<td>20 (5-27)</td>
</tr>
<tr>
<td>Onset of oestrus to ovulation (h)</td>
<td>30 (20-44)</td>
<td>34 (24-48)</td>
</tr>
<tr>
<td>LH peak to ovulation (h)</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>End of oestrus to ovulation (h)</td>
<td>12 (10-15)</td>
<td>14 (6-21)</td>
</tr>
</tbody>
</table>

If conception occurs the CL continues to secrete progesterone through most of the gestation period. This prevents further cyclic activity and ovulation, but occasionally some signs of heat may be seen in a small percentage of animals. If conception does not occur, or if the embryo dies before day 14 to 15 of the cycle, the CL undergoes destruction due to the dual action of the hormones prostaglandin F2a (PG) and oxytocin which are secreted by the uterus and ovary respectively. This allows repetition of the oestrous cycle and provides further opportunities for the animal to become pregnant.

The external signs of heat are usually more pronounced in taurine cattle than in zebu cattle and show least
The external signs of heat are usually more pronounced in taurine cattle than in zebu cattle and show least in buffalo. However, marked variations occur between and within breeds and the signs can range from very weak to very marked. The main signs of oestrus are:

- swelling and reddening of the vulva
- secretion of clear, glassy, stringy mucus from the vulva
- relaxation of pelvic ligaments
- restlessness and/or bellowing
- decreased appetite and milk yield
- desire to interact with other animals
- standing still when mounted by a bull or another cow.

Under free-range conditions, males will show interest in, and attempt to mount, females which are in heat. Also, in the case of cattle, females will interact with and mount each other during heat, but this is not common in buffalo. In the latter case, frequent voiding of small amounts of urine may sometimes be seen.

The duration of heat is usually shorter in tropical cattle breeds (mean 10 hr) than in temperate breeds (mean 15 hr). The expression of heat signs is also influenced by environmental factors such as temperature and humidity, social factors such as the dominance order of an animal in a herd and the presence of disease or painful conditions in the animal's legs or hooves. Heat detection is an important factor in the fertility of dairy cattle and buffalo. The cheapest and most easily applicable method is visual observation. In using this method, however, it is essential that the observer is aware of what to look for and is motivated. Guidelines for improving heat detection are given in Section 7.2 of this chapter.

Various aids for heat detection are available and include the following: KaMaR heat mount detectors and tail paint; movement detectors (pedometers); measurement of vaginal resistance (which declines at oestrus); examination of vaginal mucus for stretch-ability (spinnbarkeit) and crystallisation pattern; monitoring of body (or milk) temperature; and repeated measurement of progesterone concentration. Most of these, however, are not practicable under smallholder farming systems in developing countries. The use of `teaser' animals may be applicable in the larger herds with grazing management systems. Such animals include males which have been vasectomised, penile deviated or aproned, and females which have been androgenised. They are usually fitted with chin-ball markers to identify cows which they mount.

In cattle as well as buffalo, the shedding of the ovum from the ovary (ovulation) occurs after the end of the heat period, at around 12 hours in cattle and 14 hours in buffalo. The optimum time for mating is therefore during the latter part of heat or immediately after the end of heat. This is because the sperms from the male need to spend a minimum of six hours in the female reproductive tract in order to acquire the capability to fertilize an ovum (termed capacitation). The sperm can survive for 24 hours in the female tract and the ovum can remain alive for 12 hours after ovulation.

**Pregnancy and parturition**

Fertilisation of the ovum occurs in the oviduct (fallopian tube) and the resulting embryo enters the uterus after four days. The embryo undergoes rapid cell division and growth. Implantation or attachment to the lining of the uterus occurs progressively during the period 25 to 35 days after fertilisation. The embryo is called a fetus from 45 days after fertilisation.

The mean duration of gestation is 285 days in Zebu cattle and 280 days in taurine dairy breeds (range 270-290). In buffalo the mean gestation length is 310 days for river types and 316 days for swamp types (range 300-330).

The standard method for diagnosis of pregnancy is palpation of the genital tract through the rectum by a
veterinarian, which is usually done from about 50 days after mating. The criteria used for determining pregnancy by rectal palpation in buffalo are similar to those in cattle but, due to the longer gestation length, each palpable feature is first discernible about two to four weeks later, during pregnancy. Other modern methods such as measurement of hormone levels in blood or milk and ultrasound scanning can also be used for pregnancy diagnosis (Section 6.3 and 6.4).

At the end of gestation the process of calving (parturition) is initiated. It consists of three stages: dilatation of the birth canal (2-6 hr); expulsion of the fetus (30-40 min); and expulsion of the fetal membranes (2-6 hr). Under normal conditions, the process of calving should be completed in about 8 to 12 hours in cattle and six to eight hours in buffalo.

The postpartum period

After calving, the reproductive tract of the cow goes through a period of recovery called involution, during which the uterus returns to its non-pregnant size and state. This is usually completed in 25 to 35 days. However, this process can be delayed if the uterus becomes infected after calving. This can happen if the cow calves under dirty unhygienic conditions, or if it has an abnormal delivery, such as dystocia, retained placenta or prolapse of the uterus.

The sexual cycles are also suppressed during the early postpartum period. The organs which govern the hormonal mechanisms controlling the sexual cycle, which include the hypothalamus in the brain, the pituitary gland under the brain and the ovary in the abdomen, gradually recover their cyclic functional status and the cow should normally show signs of heat within 30 to 60 days after calving. However, as shown in Table 13.2, a number of factors influence the functions of these organs and, as described in the following section, the commencement of sexual cycles can be delayed and result in low reproductive efficiency.

Table 13.2. Factors which influence the commencement of ovarian activity after calving in cattle and buffalo.

<table>
<thead>
<tr>
<th>Endogenous factors</th>
<th>Exogenous factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotype</td>
<td>Nutrition</td>
</tr>
<tr>
<td>Milk yield</td>
<td>Suckling</td>
</tr>
<tr>
<td>Age/parity</td>
<td>Year/season/rainfall</td>
</tr>
<tr>
<td>Body condition</td>
<td>Thermal environment Social factors</td>
</tr>
</tbody>
</table>

Reproductive efficiency

The efficiency of reproduction can be assessed from several measures or parameters, which are termed reproductive indices. Each index provides information on a specific aspect of fertility but has its particular value as well as limitations. Therefore, in order to obtain an assessment of the overall reproductive performance at a given time or over a longer period, several of these indices need to be used. Some indices are applicable only to a herd or a population of cows, while others can also be used in individual animals.

In the case of heifers, the important indices are the age of attainment of puberty and the age at first calving. The former depends on the time of onset of ovarian activity, while the latter is influenced by the time of conception. Under free ranging conditions with access to bulls, heifers will usually conceive soon
after puberty. In confined systems, however, efficiency of heat detection, timing of service and other related factors will have important influences on the age of first calving.

The conception rate (CR) is the percentage of animals conceiving (based on pregnancy diagnosis by rectal palpation) relative to the number of animals which have been served. It is usual to calculate it either as CR to the first service only, or as overall CR. The pregnancy rate (PR) is calculated as the percentage of animals becoming pregnant (usually over a one year period) relative to all breedable females in the herd. The calving rate is the percentage of breedable females which calve during a given year. The number of services per conception (S/C) is the total number of services given to a group of conceiving cows, divided by the number of conceiving cows. These indices are all influenced by factors related to the cow, the bull or artificial insemination (AI) and the farming system.

The non-return rate (NRR) is an index often used by AI services to evaluate the success of their operations. This is calculated as 30, 60 or 90 day NRR and refers to the percentage of animals which were serviced but did not return for a repeat service within the specified period, the assumption being that they conceived. Its usefulness is limited to situations where AI is the sole method of breeding and the recording systems are foolproof. Under many tropical smallholder systems, the more likely reasons for ‘non-return’ to AI are the use of a stud bull or sale of the cow when the farmer found out that it had not conceived to AI. Thus the use of NRR by AI organisations under such conditions is meaningless.

The calving interval (CI) is possibly the single index which provides most information on reproductive efficiency, whether in an individual cow or on a herd basis. This is made up of three components:

1. Interval from calving to first oestrus (postpartum anoestrus period)
2. Interval from first oestrus to conception (service period) \(a + b = \text{`open period'}\)
3. Interval from conception to calving (gestation period)

In order to maintain optimum economic benefits under modern intensive dairy systems, it is generally accepted that the CI should be around one year. Since the average gestation length is 280 to 285 days, a cow must become pregnant by 80 to 85 days after calving in order to achieve this. The cow must commence ovarian activity early during the postpartum period, show heat, conceive readily, carry the pregnancy successfully and produce a calf. The farmer must detect heat, mate the cow at the correct time and provide adequate nutritional and other inputs.

The relative importance of these factors vary in the different smallholder farming systems. For example, under extensive free grazing conditions nutritional fluctuations due to seasonal shortages in herbage cause delays in puberty and the postpartum cycle. However, if the cows are grazing with intact bulls, they readily become pregnant once ovarian activity commences. In tethered grazing or confined systems, factors such as heat detection, timing of mating or AI quality take on more importance. The presence of the calf and suckling frequency, also influence postpartum ovarian activity in some smallholder systems.

Under many dairy systems in tropical countries a one-year CI is often difficult or impossible to achieve and, in some situations, even undesirable. In Ethiopian highland Zebu cattle, raised under traditional management, the lactation period is eight months and calving intervals average 26 months. This means that cows conceive about eight months after the end of lactation, which appears to be the period required to regain body weight and condition, to continue the cycle and conceive again. In many traditional dairy systems it is a common occurrence to have a proportion of cows calving only once every two years. Although these cows would be considered to have very poor fertility from the standards applied to improved temperate cattle, they would not even survive, let alone reproduce, under such conditions.
Similarly, the acceptability criteria used for the other reproductive indices under temperate conditions are inappropriate for many tropical smallholdings. A more realistic and achievable set of criteria need to be developed for such systems and tested for validity under the prevailing production levels and pricing structures. Table 13.3 gives the classical optimum reproductive indices for dairy cattle, together with a suggested ‘acceptable’ set of criteria for use under the more intensive and improved smallholder conditions. A similar set of criteria is also given for buffalo, with suitable adjustments to account for inherent differences, such as later maturity of heifers and longer duration of gestation.

**Table 13.3. Reproductive indices for dairy cattle and buffalo under optimum conditions and suggested ‘acceptable’ performance under improved smallholder systems in the tropics.**

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th></th>
<th>Buffalo</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Optimum</td>
<td>Acceptable</td>
<td></td>
<td>Optimum</td>
</tr>
<tr>
<td>Age at puberty (m)</td>
<td>&lt; 18</td>
<td>&lt; 24</td>
<td>&lt; 30</td>
<td>&lt; 36</td>
</tr>
<tr>
<td>Age at first calving (m)</td>
<td>&lt; 30</td>
<td>&lt; 36</td>
<td>&lt; 42</td>
<td>&lt; 48</td>
</tr>
<tr>
<td>Calving to first service (d)</td>
<td>&lt; 60</td>
<td>&lt; 90</td>
<td>&lt; 60</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>Calving to conception (d)</td>
<td>&lt; 85</td>
<td>&lt; 115</td>
<td>&lt; 85</td>
<td>&lt; 115</td>
</tr>
<tr>
<td>Calving interval (m)</td>
<td>12-13</td>
<td>13-14</td>
<td>13-14</td>
<td>14-15</td>
</tr>
<tr>
<td>First service conception rate (%)</td>
<td>&gt; 60</td>
<td>&gt; 55</td>
<td>&gt; 55</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Overall conception rate (%)</td>
<td>&gt; 80</td>
<td>&gt; 75</td>
<td>&gt; 75</td>
<td>&gt; 70</td>
</tr>
<tr>
<td>Calving rate (%)</td>
<td>&gt; 75</td>
<td>&gt; 70</td>
<td>&gt; 70</td>
<td>&gt; 65</td>
</tr>
<tr>
<td>Services per conception</td>
<td>&lt; 1.6</td>
<td>&lt; 1.8</td>
<td>&lt; 1.8</td>
<td>&lt; 2.0</td>
</tr>
</tbody>
</table>

Large variations in reproductive efficiency exist between different traditional systems in Africa, Asia and Latin America. For example in Zebu cattle, the age at first calving ranged from 23 to 58 months, the CI from 12.2 to 26.6 months, the calving rate from 20 to 90 per cent and the services per conception from 1.4 to 2.8. The values suggested in Table 13.3 will clearly not be achievable under the more harsh environments. However, there are many smallholder systems which can readily achieve these targets cost-effectively, through the use of appropriate genotypes, strategic changes in nutrition and better reproductive management.

**Effects of genotype**

The genotype of the animal determines its reproductive potential, but the end result is influenced by all the factors mentioned earlier, which we can broadly call environment. Thus a well adapted tropical zebu cow might have a relatively low inherent reproductive capacity, but may be able to achieve its full potential under the prevailing conditions. A Holstein Freisian (HF) cow which has been bred for high milk production and excellent reproductive performance under temperate conditions will, if moved to the tropics, perform well below its potential capability.

This can be illustrated from results of the importation of temperate dairy cattle into many tropical countries. Table 13.4 gives results from a study in Mauritius, where postpartum ovarian activity was monitored, using milk progesterone measurement, in locally bred dairy cows (HF and Creole crosses) in three different climatic regions and in imported pure-bred HF cows. Among the locally bred cows, those in the medium and high rainfall regions had better fertility than those in the low rainfall regions. The imported cows had very poor fertility which made them highly uneconomical for smallholder farmers.
In tropical countries with high temperature and humidity, even locally bred cows may not be able to adapt to the environment if their genotype contains a high proportion of taurine blood. For example, in the southern region of Vietnam, where continuous upgrading of the native cattle to HF has been in progress through an efficient AI service, a recent study of 600 dairy cows on smallholdings has shown that as the proportion of HF inheritance increased, the interval from calving to first AI increased and the first service conception rate decreased (Figure 13.1).

**Table 13.4. Reproductive performance of locally bred and imported dairy cattle on smallholder farms in Mauritius.**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Locally bred</th>
<th>Imported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall region</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Number of cows</td>
<td>74</td>
<td>48</td>
</tr>
<tr>
<td>Calving to first rise in progesterone (d)</td>
<td>74±36</td>
<td>84±25</td>
</tr>
<tr>
<td>Calving to first artificial insemination (d)</td>
<td>150±52</td>
<td>120±47</td>
</tr>
<tr>
<td>First service conception rate (%)</td>
<td>31</td>
<td>45</td>
</tr>
<tr>
<td>Services per conception</td>
<td>2.9</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Figure 13.1. Effect of genotype on postpartum fertility of smallholder dairy cattle near Ho Chi Minh City, Vietnam.**

The increased interval to first AI indicates that resumption of ovarian activity in these animals with more HF inheritance is compromised by the climatic and/or nutritional stresses. The lower conception rates in these could be attributed to higher rates of fertilisation failure and/or early embryonic death, which are known to occur in unadapted genotypes exposed to high ambient temperatures.

**Effects of nutrition and environment**
Nutrition has a major influence on the age of attainment of puberty. For a given genotype of cow or buffalo, heifers that are well fed will grow faster and attain puberty at an earlier age than those poorly fed. This results in an earlier age of first calving, with economic benefits to the farmer through more milk and more calves during the lifetime of the animal.

In dairy cattle, the period of early lactation is particularly stressful, in that the cow is unable to meet its nutrient requirements for high milk production through the daily feed intake. Therefore, it draws on stored nutrient reserves (fat deposits) until it attains a metabolic balance around the second or third month of lactation. Thus cows calving in poor body condition lose more weight and take longer to regain the lost weight than those calving in good condition. As a result, such cows also take longer to commence cyclic ovarian activity than well-fed cows.

It has been well established that a balanced diet providing sufficient protein and energy is essential for normal fertility to be maintained. Deficiencies in sodium, phosphorus and selenium have been shown to cause infertility, while deficiencies in iodine, manganese and zinc can also cause reproductive disorders. Beta-carotene is one of the most important vitamins. Deficiency of b-carotene can occur if animals are maintained solely on cereal straws or stovers, and can lead to silent or delayed ovulation, a low conception rate and high embryo mortality.

In tropical conditions, environmental factors such as high heat and humidity can have important inhibitory effects on reproduction. This can be a direct effect of suppression of appetite and feed intake, or an indirect one through fluctuations in the quality and quantity of feed available to the animals. For example, it has been observed that animals managed under free-range conditions in the dry and intermediate zones of Sri Lanka have a markedly seasonal pattern of calving. The majority of calvings occur with the commencement of North-East monsoon rains in October/November. This is caused by a seasonal pattern of conceptions, which occurs some 10 months earlier. The seasonal conceptions are in turn caused by stimulation of ovarian activity in the cows by the favorable nutritional conditions which prevail at this time, due to abundant good quality forages following the monsoon rains. Thus animals which calve during this season have the benefit of better feed during the period after calving and therefore resume sexual cycles early, whereas those calving at other times experience scarcity of feed as well as hot environmental conditions and therefore remain sexually inactive for a long period.

This points to the possibility of improving reproductive efficiency through adapting the breeding pattern to annual variations in climate and feed availability, or supplementary feeds to animals due to calve during adverse periods. Supplements should be provided two months prior to calving and the early postpartum period.

**Effects of management practices**

Management practices such as suckling of calves can influence the resumption of sexual cycles after calving. A field survey completed in Sri Lanka showed that under one traditional system of management in a village in the dry zone, the reproductive performance of the cows was excellent. In this system, calves were raised separately from their mothers from the time they were one week old and allowed access to the cows only once a day for suckling.

Subsequent research tested six different suckling regimes: free suckling; free suckling followed by weaning at day 45, day 60 or day 90; suckling once a day from day seven; and suckling twice a day from day 7. The results (Figure 13.2) showed that free suckling resulted in the lowest pregnancy rate at 150 days. Weaning at 45 days resulted in the highest pregnancy rate, but calf mortality was very high. Weaning at later stages did not improve fertility over controls, nor did it reduce calf mortality to acceptable levels. Suckling once or twice a day improved fertility, albeit less than weaning at 45 days, but...
calf mortality was low and similar to that in controls. The growth rates of calves during the first three months was lower with limited suckling than with free suckling, but this difference was not observed from four months onwards. Similar studies under different smallholder systems where suckling is practiced should be undertaken, to determine the most appropriate strategy for improving reproduction, without compromising calf growth or survivability.

![Figure 13.2](http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap13.html#TopOfPage)

**Figure 13.2. Effects of different suckling regimes on pregnancy rates in buffalo cows at 90, 120 and 150 days postpartum and on calf mortality (Abeygunawardena et al 1996a).**

Research has also shown that, apart from the suckling stimulus, the mere presence of the calf near its dam, and the degree of direct contact by touch, smell and sound, can delay the onset of postpartum ovarian activity in the dam. This is thought to be mediated by substances such as β-endorphin and insulin-like growth factor (IGF). Therefore a further method of improving reproductive efficiency is to change the system of calf feeding so as to restrict the interaction between the cow and its calf.

**Effects of breeding management**

Management decisions of farmers as well as their knowledge and skills have important effects on the reproductive performance of cows. The farmer must decide on the age and or weight at which heifers are mated, and the interval after calving when cows are mated. In the case of heifers, mating too early will result in a longer postpartum anoestrus period after the first calving, while mating late will result in loss of production time. Cows which have normal calvings and uncomplicated uterine involution can normally be mated if they show heat anytime after 45 days, but full fertility may not be obtained until about 60 days after calving. Delaying mating beyond 60 to 90 days will result in economic losses in many production systems.

Some smallholder farmers, such as those in Sri Lanka and Mauritius, commonly delay mating for three to six months after calving. This is due to a belief that mating too early will result in a shortened lactation and lowered milk production. These farmers require education regarding the advantages of early mating in terms of greater lifetime productivity of milk and calves by an individual cow.

Two major deficiencies in many smallholder systems are poor detection of heat and mating of the cow at
the incorrect time. Studies using progesterone measurement have shown that under certain conditions only 30 to 50 per cent of ovulations occurring during the postpartum period will be detected by farmers. On the other hand, of the heats detected by farmers, some 15 to 20 per cent may be false. Thus efficiency, as well as, accuracy of oestrus detection needs improvement through education and training.

Timing of mating is critical for conception, but this may sometimes be outside the control of the farmers themselves. For example, the AI services may not be readily available, or accessibility to stud bulls may be limited. A further contributor to poor fertility is the tendency of farmers to assume that a cow will be pregnant once it has been serviced. They therefore neglect to look for returns to service and find out many months later that the cow is not pregnant, by which time valuable production time has been lost. On the other hand, many farmers believe that met-oestrus bleeding (Section 2.2) is a sign that the animal has not conceived to the preceding mating. A further misconception prevalent in certain cultures is that cows come in to heat mainly around the time of the full-moon.

Infertility and sterility

Infertility means a reduced ability or temporary inability to reproduce, while sterility is a complete and permanent inability to reproduce. When infertility or sterility occurs in an individual animal or a herd, it is essential that the underlying causes are accurately identified. It is only then that a rational decision can be made to overcome the problem and prevent any future occurrence.

Understanding a particular farming system requires:

- background knowledge of the farming system and environment
- review of the operational aspects of the particular farm
- full history of the current problem (on an individual and herd basis)
- thorough clinical examination of affected animal(s) or entire herd
- special diagnostic tests where indicated.

Once the problem has been identified, a decision has to be made on the most appropriate corrective measures. These may involve changes in management, nutrition or breeding methods, treatment or culling of affected animals and follow-up procedures. The approach selected should depend on practicality, economics, socio, and cultural considerations.

Delayed puberty

Under many smallholder management conditions the replacement heifers receive very little special attention, resulting in late age at puberty, delayed first calving and economic loss to the farmer. This is particularly evident in situations where calves with a high proportion of taurine inheritance have resulted from artificial insemination (AI) programs, but are kept under the same stressful environments as native calves, with inadequate feeding and lack of parasite or disease control. In undertaking such genetic improvement programs the AI and extension services must ensure that smallholders understand, and are indeed able to provide, the increased inputs required to obtain the benefits of rearing improved genotypes.

A small percentage of calves may have congenital abnormalities which will delay or completely prevent the attainment of puberty. Such animals should be detected as early as possible and culled. Also, since many of these conditions have a hereditary basis, such animals should not be used as breeding stock.

Congenital ovarian abnormalities include absent (agenesis), undeveloped (aplastic) and under developed (hypoplastic) ovaries. If the condition is bilateral the heifer will be sterile, but in unilateral cases ovulation...
can occur from the normal ovary. However, such animals should never be used as breeding stock as the condition will be perpetuated in subsequent generations. Diagnosis of the condition is possible by rectal palpation of the ovaries.

In cattle and buffalo, when twins of unlike sex (that is, male and female) are born, the female calf is usually sterile. This is due to a condition called freemartinism, where the reproductive organs of the female twin have been modified due to mixture of blood from the male twin during early pregnancy. The influx of primordial germ cells and testicular hormones from the male twin result in ovo-testes, undeveloped female tract and, sometimes, development of male accessory glands. Externally there may be a well-developed clitoris and a tuft of hair at the ventral vulval commissure. The vagina is usually shorter than normal and diagnosis can be confirmed by rectal palpation.

If a thorough clinical examination reveals no other abnormality apart from inactive ovaries, the recommended course of action is to improve nutrition and management. If rectal palpation reveals the presence of a CL in one of the ovaries and one or more follicles of varying size, it indicates that the heifer has probably commenced the sexual cycle but the farmer has failed to observe heat. In such cases advice should be given on improving heat detection.

It should be noted that heifers with delayed puberty should not be treated with hormones to induce them to this stage. This can result in undesirable traits being passed on to the next generation and a decline in herd fertility.

**Anoestrus**

Anoestrus is the absence of signs of oestrus. It can occur in normal physiological situations, such as during pregnancy and the early postpartum period. It is considered to be a cause of infertility when it occurs at times when breeding is required, which is mainly at the expected time of breeding after puberty in heifers and, depending on the genotype and production system, after 45 to 90 days from calving. The underlying causes of anoestrus are; an abnormally extended period of postpartum ovarian inactivity (termed 'true' anoestrus), cystic ovaries and uterine infections, pregnancy disorders leading to persistence of the CL, or non-expression by the animal (silent ovulation), and failure on the part of the farmer to detect heat.

If the condition is true anoestrus, the first priority is to ensure that nutrition and management are satisfactory. If the calves are being suckled, or tied in close proximity to the dams, modifications compatible with the management system should be instituted. Treatment with hormones gives variable results and should only be attempted where the body condition is good, reproductive tract normal and the ovaries of normal size with indications that small tertiary follicles are present. Two approaches are available. The first involves either stimulation of FSH and LH secretion by treatment with Gonadotrophin-Releasing Hormone (Gn-RH), or simulation of FSH with Pregnant Mare Serum Gonadotrophin (PMSG). The second approach is to use the so-called 're-bound' effect, by providing exogenous progesterone for a period of 10 to 12 days, followed by abrupt withdrawal. This can be achieved with orally active compounds (which are cheap but impractical in many situations) or silastic devices impregnated with progesterone which can be placed in the vagina or implanted under the skin of the ear.

Conditions such as luteal cysts and uterine infections require appropriate treatment. Early cases of both conditions usually respond well to the luteolytic effect of prostaglandins (PGs), but the latter condition may also require treatment with appropriate antibiotics. Long standing cases, however, may relapse and require culling on economic considerations. Mummification can also be treated effectively with PGs, but maceration usually causes permanent damage to the uterus and impairs future fertility.
maceration usually causes permanent damage to the uterus and impairs future fertility.

When evidence of ovarian activity is found in animals claimed by the owner to be an-estrous, it is often difficult to determine whether the problem lies with the cow (silent ovulation or sub-estrous), or with the owner (missed estrous). Based on the findings from rectal palpation it is often possible to predict approximately when the next heat can be expected, and the owner can therefore be instructed on what to look for, and when. If this also fails it is possible to induce estrous by injecting PGs when a mature CL is present then focus heat detection over the next three days, followed by mating at the appropriate time.

**Repeat breeding**

Repeat breeding is defined as the failure to conceive in spite of three successive services given during `normal' oestrous cycles, with no detectable abnormality. Causes of repeat breeding can include, factors that relate to the cow, the bull or AI service, and the management practices on the farm.

From the etiological viewpoint, there are two main reasons why a cow returns to heat after one cycle length from service. The first is failure of fertilisation. Here the ovum and sperm either do not meet, or meet but fail to fuse. The main reasons relating to the female are: congenital abnormalities (segmental aplasia of oviducts, uterus or cervix); acquired abnormalities (ovaro-bursal adhesions or occlusion of oviducts due to injuries during calving or scar tissue formation after infections) and ovulatory disorders (delayed ovulation and non-ovulatory heat). In the case of natural service the factors relating to the bull include its fertility, the timing of service in relation to heat, and the number of services during one heat period. Where AI is used, the original fertility of the semen, its processing, storage and handling, the timing of the service and the skill of the inseminator have important effects.

The second reason for return to heat after one cycle length is early embryonic death (EED), which is defined as death of the embryo before day 14 to 15 of the cycle. Since such death occurs before the mechanism of `maternal recognition of pregnancy' is activated, the reproductive system acts as if the animal did not conceive and produces the luteolytic hormones which destroy the CL, resulting in heat at the normally expected time. On the other hand, with late embryonic death (LED) which occurs after day 16 to 17, pregnancy recognition has already occurred and the luteolytic hormones have been suppressed. Thus the reproductive system requires more time after LED to re-initiate the luteolytic mechanism and the cow returns to heat at a later time. The factors responsible for EED are atypical fertilisation (for example, polyspermy due to aging of the ovum), genetic defects in the ovum or sperm (lethals) and unfavorable uterine environment.

Accurate diagnosis of the causes of repeat breeding requires a careful consideration of all possible factors, on an individual as well as herd or population basis, and systematic elimination of each unlikely cause. If a clinical abnormality is found in the cow, a decision has to be made whether to treat or cull the animal. If deficiencies in management or breeding procedures are detected these should be corrected. However, in many cases a definitive diagnosis is not possible. In such cases, the best treatment is to keep the cow with a proven bull during a period of normal heat or, if this is not possible, to do a repeat AI using good quality semen and a skilled inseminator. Indiscriminate treatment with hormones or drugs in the absence of a definitive diagnosis usually serves only to complicate the problem.

**Infectious causes**

Infertility can be caused by specific diseases or non-specific infections. Specific infections can be bacterial, viral or protozoal. A brief outline of these is presented here.

Brucellosis is a bacterial disease which can infect animals at any age, but manifests itself only during pregnancy, causing abortion during the last three months of pregnancy. Infection spreads by contact with,
or ingestion of, aborted material and sometimes through the milk. When first introduced into a herd, it can cause a 'storm' of abortions. Subsequently abortions will be rare but infertility, still births, retained placenta and other related disorders will persist. The disease is communicable to man and causes a condition called undulant fever. Diagnosis is made by testing milk (on a herd basis) or blood (for individual cows) using simple plate or tube agglutination tests, or more sophisticated methods such as the complement fixation test or the Enzyme-Linked Immunosorbent Assay (ELISA).

Leptospirosis is another bacterial disease which causes abortions in late pregnancy and is also communicable to man. Spread occurs through contact with, or ingestion of, the organism which is excreted in the urine of infected animals. Diagnosis is possible through tests on blood and urine and the disease can be cured by antibiotic treatment.

Campylobacteriosis (vibriosis) is a bacterial disease which is usually transmitted during mating. Another very similar condition, also acquired venereally, is Trichomoniasis, caused by a protozoal organism. Both diseases result in death of the embryo during the first three to four months of pregnancy. This is usually followed by a uterine infection which can persist for a variable period. Cows can transmit the disease to bulls during mating. Diagnosis is possible by culture of the organisms or serological tests. Appropriate treatment of infected cows followed by sexual rest for two to three months aids recovery, but bulls usually remain as asymptomatic carriers of the disease and should be culled.

The main viral infections which causes specific reproductive problems in bovines are bovine herpes viruses 1 and 4, bovine virus diarrhea virus and parainfluenza 3 virus. These can cause infertility through fertilisation failure, embryo mortality and abortion.

Non-specific infections are caused mainly by bacteria which invade the reproductive tract, usually through the cervix. This occurs commonly when unhygienic conditions prevail at the time of calving, natural mating or AI. Initially endometritis will occur, which can progress to metritis and pyometra. With endometritis animals will usually cycle and the only external signs may be white streaks of pus in the clear mucus discharged at the time of oestrus, but such animals will have poor fertility due to non-fertilisation or EED. With metritis and pyometra there is usually an-estrous due to persistence of the CL. Discharge of pus may be absent, slight or copious, depending on whether the cervix is closed or open.

The best method of overcoming uterine infections is to induce estrous, because the physiological action of estrogen on the uterus causes evacuation of its contents and activates the natural defense mechanisms. This can be done by injecting PGs when a CL is present.

**Accidents and miscellaneous causes**

Once conception has occurred, death of the embryo can occur due to a variety of causes. Genetic abnormalities in the embryo, climatic or other stresses and specific or non-specific infections are important causes. Even under optimum conditions embryonic death occurs in 20 per cent of conceptions.

After 45 days, when the embryo becomes a fetus, the main causes of death are genetic abnormalities, toxins, severe stress, accidents and specific infections. Fetal death will be followed by either retention of the fetus in the uterus (resorption, mummification or maceration) or its expulsion (abortion). Under normal conditions abortion should not exceed three to five per cent of all pregnancies. However, all cases of abortion should be reported so that investigations take place to rule out the presence of infectious disease.

**Male fertility, natural breeding and artificial insemination**
Male fertility

In the male, puberty is a gradual process with a progressive increase in sperm production and mating capacity. Bull calves of many temperate breeds will show libido before one year of age, but fertility may not be reached until 14 to 16 months of age. Puberty is usually defined as the time at which a male becomes capable of impregnating a cow and, in bovines, requires the presence of at least 50 million sperm per ejaculation, with more than 10 per cent showing progressive forward motility. As in the female, puberty is influenced by genotype, nutrition and many other factors.

The volume of semen produced per ejaculate varies from two to five milliliters in young bulls to five to 15ml in older ones. A normal sample should contain one to three billion ($10^9$) sperm per milliliter, with over 60 per cent of the sperm being alive and showing vigorous motility. Many specialised tests are available for evaluating a sample of semen, including microscopic, biochemical and computer-based methods.

The process of selection, rearing and use of breeding bulls is very important if optimum fertility is to be obtained and depends on whether they are intended for natural breeding or AI. In all cases, however, breeding bulls must be superior not only in their genetic potential, but also in their reproductive characteristics. They must have normal and well-developed reproductive organs, produce excellent quality semen, have good libido and be able to mount and service females efficiently.

Natural breeding

Bulls can be used for two main types of natural breeding, either free mating in the range or controlled hand-mating. In the former system heat detection is carried out by the bull and cows in heat are usually mated several times during each heat period. One bull can cover 40 to 50 cows per year, provided there is no marked seasonality in the occurrence of heat. In large herds several bulls may have to be used in rotation, since it is often impossible to introduce two or more bulls at the same time due to aggressive behaviour towards one another.

In hand-mating systems heat detection and timing of service is carried out by the farmer and each cow is mated once or twice during each heat period. In this situation a bull can be used on three to four cows per week or 150 to 200 cows per year. If a bull is used after a period of sexual rest exceeding two weeks, the first ejaculate is usually of poor quality and therefore a repeat mating should always be done after several minutes.

Artificial insemination (AI)

One of the oldest reproductive technologies applied in animal breeding was AI and it continues to be the most important one even today in many livestock production systems in temperate as well as tropical regions.

With AI one ejaculate from a bull can be used to serve 400 to 500 cows and therefore one bull can produce sufficient semen for more than 50,000 cows per year. With current technologies of semen preservation this means that the top one percent of bulls in the world can be selected and used on cows which are widely separated in space and time. Also, farmers do not have to undergo the costs or hazards of rearing breeding bulls and can have access to a very wide range of bulls. Many of the infectious reproductive diseases can also be controlled by the use of AI.

On the other hand, AI has several disadvantages. The overhead costs of establishing and maintaining AI
centers, equipment, personnel and their training are high. It requires a good infrastructure such as a network of AI points, semen distribution, field inseminators and, if frozen semen is used, a regular supply of liquid nitrogen. The farming community must also be educated in heat detection and timing of service and a reliable system of communication with the AI service should be in place. A possible hazard is the transmission of undetected genetic defects or diseases.

There are several methods for the preservation of semen (Table 13.5). The most widely used is deep frozen semen, but in many tropical countries where the infrastructure is not adequately developed other types of semen can be used effectively. For preservation the semen is diluted in an artificial `semen extender' which contains various substances such as chemical buffers (phosphate, citrate, Tris); protectants against cold shock (egg-yolk, milk, coconut milk) and freezing damage (glycerol); sources of energy (fructose); and antibiotics. Depending on the method of preservation each insemination dose will contain between 7 to 30 million motile spermatozoa.

Table 13.5. Characteristics of the main types of semen preservation and storage.

<table>
<thead>
<tr>
<th>Type</th>
<th>Temp. (oC)</th>
<th>Storage Medium</th>
<th>Packaging</th>
<th>Period of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient</td>
<td>+ 20-30</td>
<td>Anaerobic/CO2</td>
<td>Vials, 0.5 or 1 ml</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Chilled</td>
<td>+ 4</td>
<td>Refrigerator</td>
<td>Vials, 0.5 or 1 ml</td>
<td>2-3 days</td>
</tr>
<tr>
<td>Frozen</td>
<td>- 79</td>
<td>Solid CO2</td>
<td>Pellets/ampoules, 1 ml</td>
<td>Several years</td>
</tr>
<tr>
<td>Deep frozen</td>
<td>- 196</td>
<td>Liquid nitrogen</td>
<td>Straws, 0.25 or 0.5 ml</td>
<td>Several years</td>
</tr>
</tbody>
</table>

The fertility obtained from AI is influenced by a variety of factors. Those related to the cow were described in Sections 3 and 4. Factors which are within the control of the AI center producing the semen include, the level of fertility of the bull, the original characteristics of the particular ejaculate, and the procedures used in its processing, packaging and storage. Once the semen leaves the AI center its quality will also be influenced by the procedures used in transport, storage and handling in the field. A deficiency in any one link in this chain of events can make a particular dose of semen completely ineffective.

The final determinant of the success of an AI is the inseminator. All AI technicians have to undergo a specific course of training, and in some countries also an apprenticeship, before certification. However, many personal factors such as inherent dexterity, motivation and the regularity of performing AI also influence the fertility rate achieved. From a technical point of view the aspects which need special attention are the thawing and handling of semen, the handling of the cow and its genital tract and the correct placement of semen.

Modern reproductive technologies and potential applications

A variety of modern reproductive technologies are now available to livestock breeders and these have revolutionised livestock production in industrialised countries. While some of these technologies are also applicable in tropical smallholder dairy systems with little modification, others require comprehensive evaluation and adaptation under specific local conditions before they can be used effectively.

Oestrus synchronisation

Synchronisation of oestrus is the act of making a number of cows come into heat at the same time. This
Synchronisation of oestrus is the act of making a number of cows come into heat at the same time. This allows better planning of breeding activities and wider use of AI. Cows to be used in such programs must not be pregnant and be undergoing normal sexual cycles. The strategy is based on controlling the luteal phase of the oestrus cycle and can be achieved through two main approaches: (1) extending the luteal phase by treatment with exogenous progesterone or progestagens, or (2) terminating the luteal phase by treatment with PG or its analogues.

The former method employs silastic devices containing the hormone progesterone placed under the skin of the ear or in the vagina of the cow for a period of 12 to 14 days, together with a dose of oestradiol at the commencement of treatment. The latter method involves the use of two PG injections given 10 to 12 days apart. Animals usually come into heat two to three days after the treatment regime and it is possible to inseminate them on a pre-planned basis. Two inseminations are necessary per cow, at 48 and 72 hours after withdrawal of the progesterone treatment, or 72 and 96 hours after the second PG treatment. Under certain management systems a variation of the PG technique is used, where the first dose is given to all cows, heat is observed and those showing signs are served twice, at an interval of 24 hours. The second dose is then given only to those not previously showing heat and they are served twice without heat detection, at 72 and 96 hours.

This technology has been used in smallholder systems in many countries with variable results. In order to ensure success it is important that animals selected for treatment are healthy, in good condition and cycling, and are not stressed or handled roughly during treatment and AI. Also, the treatment regimes and timings should be strictly adhered to without making shortcuts for the sake of convenience.

**Embryo transfer (ET)**

This involves the use of superior females as donors of embryos which are then implanted in recipients (surrogate mothers). It allows these superior animals to produce many more calves during their lifetime than would be possible by natural means. There are now several variations of embryo transfer, including multiple ovulation embryo transfer (MOET), oocyte recovery at slaughter and *in vivo* ovum pick-up technique.

In MOET the donors are induced to shed several ova instead of one, through a regime of hormone treatment called super-ovulation. The ova are then fertilised by inseminating the donor with semen from a superior bull and the embryos are collected from the uterus of the donor after five to six days. The embryos are examined under a microscope, any abnormal or undeveloped embryos are discarded, and each healthy embryo is either transferred directly to a recipient or stored in liquid nitrogen for future use.

In the techniques of oocyte recovery at slaughter and *in vivo* ovum pick-up, the immature ova present in the ovarian follicles of cows are harvested, in the former case by direct visualization of the ovaries in slaughtered animals, and in the latter case with the help of ultrasound scanning in live animals. The ova are then cultured in the laboratory until mature, fertilized *in vitro* and transferred to recipients.

Although ET is being used commercially in some industrialized countries, its main potential advantage for tropical countries may be in the possibility of importing frozen embryos instead of live animals. This might be justified where nucleus-breeding stocks need to be established on state or other institutional farms. ET is unlikely to have direct applications in smallholder systems in the near future.

**Hormone assay**

The concentration of progesterone, which is present in minute amounts in the blood and milk of females can be measured using techniques such as radioimmunoassay (RIA) and enzyme immunoassay (EIA).
cattle and buffalo, a relatively high concentration at a given time indicates the presence of an active CL in the ovaries, while basal concentrations indicate its absence. It is therefore a useful technique for monitoring ovarian activity, but requires repeated samples to detect, for example, onset of puberty or initiation of postpartum ovarian activity.

However, one practical application is in identifying animals which have not conceived to AI, by analyzing a sample collected between 20 to 23 days after AI. Since the CL will regress about 16 to 17 days after the previous heat if the animal does not become pregnant, a basal progesterone level at 20 to 23 days after AI is an almost infallible indicator of non-pregnancy. In contrast, a high progesterone level only indicates that the animal may have conceived, since other conditions, for example, AI during luteal phase, persistent CL, luteal cysts, and late embryonic death, will also result in elevated progesterone at this time.

The advantage of the progesterone test is that non-pregnant animals can be accurately identified at an early stage, and action taken to observe them closely for heat to allow them to be mated again at the correct time. Animals with high progesterone levels should also be observed for returns to heat and, if not seen in heat, examined by rectal palpation at about 60 days after mating to confirm pregnancy. The main disadvantage of the test is that the analyses by RIA and EIA have to be done in a laboratory with specialized equipment. Thus the logistics of getting the samples to the laboratory and the results back to the farm, preclude widespread use of these methods. In an attempt to overcome such problems, simple cow-side tests on milk, using dip-sticks and strips based on a colour change, which signifies low and high progesterone levels, have been developed. However, they are still too expensive for routine use even in most industrialized countries and their stability and reliability under tropical conditions have not yet been evaluated.

If cheap and reliable qualitative cow-side tests for progesterone can be developed in the future they will undoubtedly be valuable for improving reproductive efficiency under many smallholder dairy production systems of the world.

**Ultrasonic imaging**

The use of ultrasound as a diagnostic technique has made an important contribution to the understanding of reproductive problems in farm animals. The earlier methods such as those based on the Doppler principle have now been superseded by real-time ultrasound machines with two-dimensional on-screen images. The most practical type of instrument for use in cattle and buffalo is one based on real-time B-mode ultrasound and equipped with a linear-array 5 or 7.5 MHz intra-rectal probe.

The method is non-invasive and interactive, it can be used for imaging the uterus, ovaries and related structures. With experience, pregnancy can be diagnosed as early as 10 to 15 days after mating. However, some of those conceived will not survive, due to the natural occurrence of embryonic deaths in about 20 per cent of conceptions. In practice it is more common to perform diagnoses at 20 to 30 days after mating, when the embryo and its heartbeat can be discerned. At later stages, the age can also be deduced from the heart rate and length of the embryo.

The value of the technique, as with progesterone assay, is in detecting non-pregnant cows by 18 to 20 days, so that they can be observed more closely for a return to heat and mated at the correct time. The method is now being used increasingly by veterinarians in industrialized countries. The main limitations to its application in developing countries at present, are the capital cost of equipment and the dearth of veterinarians experienced in the method. However, there are indications that simpler, more portable and possibly cheaper instruments will be developed in the future. If so, this technique could become a valuable tool for veterinarians servicing smallholder farmers.
Management of reproduction for optimum efficiency

Genotypes, records and general management

The genotypes of animals which are raised in smallholdings must be compatible with the environment and the available resources, including the knowledge and skills of the farmers. Thus cows must be served with bulls or semen of the appropriate genotype and replacement stock must be selected on defined criteria. Inbreeding should be avoided. It should be the responsibility of the service providers (state extension services, AI organisations, and co-operatives) to provide the necessary information to smallholders.

Since most reproductive traits have a low heritability, it is generally not feasible to select for high fertility under smallholder conditions. However, it is essential that selection against infertility takes place by eliminating genetically abnormal or infertile animals from breeding, by culling. This is not easy in situations where herd size is very small and the farmer may have only one replacement heifer. In such situations schemes such as subsidized heifer exchange programs need to be considered.

Records are an indispensable component of modern dairy farming, but are usually non-existent on most smallholder farms. The animals may be identified only by name and are often confused, even by the farmer. The use of at least a simple system of identification and recording, should be encouraged in all smallholder systems. This could be as simple as different colored nylon cords on the necks of cows and a wall calendar on which calvings and services are recorded.

Other aspects which need addressing are: appropriate feeding of calves, heifers and cows; minimizing the negative effects of suckling and cow-calf interactions; provision of adequate water for drinking; alleviation of heat stress, particularly in buffalo; and control of parasites and diseases, as described elsewhere in this book.

Heat detection and mating

The most suitable method of heat detection will depend on the production system. If cows are continuously tired, there are no opportunities for them to manifest interactive sexual behaviour. Thus physical signs alone form the criteria and their detection requires knowledge as well as motivation. In such systems cows should be checked at least three times per day. Sometimes the only signs visible may be swelling of the vulva and a discharge of clear mucus. In buffalo even the latter may be seen only on the floor when the animal is lying down. Observing the response of the animal to pinching of the clitoral region or to pressure on the lumbar area can also be used for confirmation.

In systems where there are several cows and they are allowed to interact at pasture or milking time, observations for homosexual and other estrous behaviors should be carried out at least three times per day, for at least 15 to 20 minutes each time. Particular attention should be paid to cows that have come into heat earlier, irrespective of whether they had been mated or not. Such animals must be observed for possible return to heat, from the 18th day after the previous heat. If they show heat signs again this usually means they have not conceived so they must be mated again. The most important aid to heat detection is a record of when a cow has been in heat previously.

Once heat has been detected the next step is to ensure that the cow is mated at the optimum time, which is during the latter part of the heat period or around 12 to 18 hours after the start of heat. If hand-mating is done with a bull, two services with an interval of six to 12 hours is recommended. When AI is used, cows detected in heat during the morning should be served in the afternoon of the same day and cows detected in heat during the afternoon or morning should be served the next morning.
in heat during the afternoon or evening should be served the next morning.

Mated cows should not be subjected to undue excitement, rough handling or heat stress for at least one week, as it has been clearly shown that a rise in body temperature during this period can result in death of the embryo. If a cow continues to show heat signs for more than 12 to 24 hours after mating, a repeat mating should be carried out.

If blood discharge is observed in a non-pregnant heifer or cow which had not been seen in heat over the past three to four days (met-oestrus bleeding), it usually means that the animal either had a silent ovulation or the farmer missed the heat. Such animals should be closely observed again starting 17 days later.

**Care of pregnant and parturient animals**

Pregnant cows should be managed so as to prevent stress and accidents. They must be dried off two months before the expected calving date (seven months after conception in cattle and eight months after conception in buffalo) and fed well during the dry period to allow accumulation of body reserves. Cows due to calve should be washed and moved to a separate clean pen if possible. Reproductive problems which occur during pregnancy or around parturition can sometimes be very serious and therefore should receive prompt veterinary assistance.

**The postpartum period**

The vulval discharges which occur after calving should cease by about 15 days. Their persistence indicates delayed involution or uterine infection which will require treatment. This is more likely to occur in cows that have had abnormal calvings.

Cows under good nutrition and management may commence ovarian activity within one month of calving. However, if the first heat occurs earlier than 45 days after calving, it is advisable to skip this heat and serve at the next one. If the calving and uterine involution have proceeded without complications, the cow can be served at the first heat which occurs after 45 days. In cows that have had calving difficulties or infections during the postpartum period mating should be delayed until about 90 days after calving.

In order to maintain optimum reproductive health in a herd, veterinary assistance should be obtained if the following conditions occur in heifers or cows:

- abnormal discharges persisting more than 15 days after calving
- no heat observed by 60 days after calving (90 days in some systems)
- no conception after more than three repeated services
- abnormal discharges at time of heat, for example, flaky mucus, or at other times, for example, pus
- difficult calving, retained placenta or other reproductive disorders.

**References and suggested reading**


Chapter fourteen
Herd recording
I. Risstrom

Introduction

Dairy farmers the world over, no matter what climatic environment they farm in, have a desire to milk better cows than the cows they currently have in their herds. To help achieve this goal, a service known as herd testing or herd recording, has been developed in the major dairying countries of the world. The smaller tropical dairy farmer is no different, as family income will also increase if more productive dairy cows are milked.

For a herd recording service to be of benefit to the tropical dairy farmer, it needs to focus on the production traits that are important in a particular country. For example in Australia, herd recording programmes focus on kilograms of protein and milk fat produced as these are the products for which most Australian dairy farmers are paid. In Thailand, dairy farmers are paid for litters of milk with a bonus for milk with a fat test percentage above a set standard, and a penalty if it is below that standard. For a herd recording programme in Thailand to be relevant to farmers, it needs to focus on litres of milk and fat test percentage. It is important that the herd recording service provider, whether it be a government department, a university extension department, or a farmer-owned and controlled co-operative or association, focuses on the relevant economic needs of the dairy farmers they are servicing.

In any development project a solid foundation is required. The foundation of a successful herd recording service is a national cow and sire identification system. With computer technology this is a simple task, but none the less, extremely important. Sire identification is important as the use of artificial insemination in small tropical dairy herds is the most likely method of mating cows, and if this is the case, they have another important management tool in the production improvement of their herds.

In addition to national cow and sire identification, there needs to be a national farm identification system as well, which can link farms in provinces or areas. This allows cows and their data to be transferred when required, and it also allows department officers to use collective herd recording data to formulate appropriate industry policy.

The primary purpose of a dairy herd recording system is to measure production of individual cows within a herd and to thereby support overall breed improvement. This can be referred to as production data. To start a lactation, a cow has a `calving date’ and at the end of a lactation a `drying off’ date. These can be referred to as cow event data, and be used in the calculation of lactation production. By collecting some additional `cow event’ data such as; identified heat dates, mating dates and sires used, calving difficulty information, and health events such as mastitis, feed problems, and reproductive problems and their treatments, a very useful bank of data is developed to help farmers to better manage their herd. It also provides industry data to identify health issues and management issues that department field officers can use to help farmers improve the productive performance of their cows.

When a herd recording programme and service is being established, it is important to keep it simple and relevant to the needs of the dairy farmers who must be able to easily identify the benefits of participating in the programme.
Organising herd recording

Governments can stimulate the creation of herd recording systems, and over decades, reduce their involvement to zero as the functions become clear to beneficiaries. Farmer organisations or private companies servicing farmer organisations become the long term organisers and managers of viable herd recording systems. Beginning with a national genetic improvement programme, breeding objectives should be translated into measurable production traits which can be regularly and readily recorded. Breed societies which manage pedigree herdbooks form a critical component to herd recording systems both as recorders and thus providers of information to the central system, and as users, to continually improve production of pedigree cows.

Farmer organisations such as dairy farmer federations, breeding associations, dairy farmer co-operatives, regional service providers and national farmer organisations can form the management committee of herd improvement schemes. The committee receives data from co-operative, regional and other farmer groups to process through its own data processing centre, privatised systems of government, or commercial houses. Data processing centres also operate herd-recording services although some smaller herd recording services may send milk samples elsewhere for analysis.

Large artificial breeding centres test the majority of bulls although some smaller centres may offer a service to farmers to collect semen on-farm for later use on the same farm. The importance of imported frozen semen in upgrading dairy herds in the tropics requires that this be from proven bulls to ensure a contribution to national herd improvement programmes.

Data collection and information flows are indicated in Figure 14.1. From the farm level, individual animal records are collected by dairy co-operatives or an equivalent farmer grouping. Milk quality is determined separately through analysis of samples received at the co-operative, factory, or in some cases, special testing laboratories. Data on herds and individual animals is collated in a central data system which may be developed by a co-operative or, in the first instance, a government instrumentality. Information from the central data system is fed back to the farmer for her/his management decision-making, as well as being analysed further in a national programme which links to a progeny testing facility as a tool for selecting sires.

In Australia for example, where no government incentives operate, for example, around 55 per cent of dairy farmers performance record their herd. They use herd recording to:

- monitor Production Index and Cell Counts
- maintain a register of pedigree and assist accurate identification
- project calving date
- facilitate certification related to sale of stock.

The two principal uses for herd recording data are:

1. estimate total yield per animal, and
2. use these estimates for genetic evaluation purposes.

Information on Somatic Cell Count, an indication of mastitis, and yield is used by farmers for treatment and feeding decisions for individual cows. At the national or breeding company level progeny testing of bulls is critical as, through artificial insemination, this is the fastest means of making genetic change (Figure 14.2). ‘Proving’ bulls is undertaken by selecting bulls expected to produce high performing offspring and recording the milk production, reproductive and other performance of female offspring across as many herds as possible. Once the value of the bull is determined, the price of semen from the bull is usually adjusted.

![Figure 14.2. Cows artificially bred versus naturally bred.](http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap14.html#TopOfPage)

The International Committee for Animal Recording issues guidelines for cow identification, recording of parents, production and other traits, supervision of recording and yield calculation. This facilitates consistency of information across countries.

### Data handling and processing

The methods followed traditionally in countries with established record-keeping systems are based on:

- pre-printed milk production sheets, sent from the processing centre to field technicians, including cow identification, last recorded status change, and information from recent days
- testing of herds on average once per month; most herds having all daily milk and milking samples recorded
- completed barn sheets forwarded to laboratories with milk samples
- test results included with milk weights, breeding dates, and other status changes on computer
- merged data transmitted to processing centres
- processing centres checking information before adding it to the system
- management reports processed and mailed to individual dairy farmers.

The keeping of dairy records can be divided into the main activities of:

- identification of cattle
- breeding records
- milk production records
- feeding and health records.

### Identification of cattle

Identification of dairy cattle requires preliminary planning. Animals may be identified by their name or a number depending on the preference of the smallholder. The obvious use of identification and records is when somebody assists in milking and the identification of an individual cow can be used to provide specific instructions about any special care needed during milking. Pure-bred animals are identified as part of a registration process which assists in breeding; in many circumstances, a premium value is placed on registered pure-bred animals.

Information should be recorded when it occurs. Putting this off leads to omissions and errors. A good herd recording system will include identification of each calf as soon as possible after birth. In addition to the identification name or number, the calf's birth date, its size, name and its sire and dam's names should be recorded on a simple identification record.
Identification systems may be either temporary or permanent. Ear tags, neck chains and ankle tags are usually temporary as they can be easily lost by an animal allowed to exercise or graze in a field. Permanent marks are those which cannot be lost and include hot brands, freeze brands, tattoos, and photographs. All identification systems have drawbacks such as the difficult application of brands and tattoos. For this reason a combination of systems may be used. Numbers allocated to individual animals may be simply consecutive, or include specific meaning for the animal, for example the number A801 might refer to the first calf born during 1998 to the sire (semen) identifying number A. Such coding is useful in large herds with multiple sires, but may not be necessary for most smallholders.

Where animals are maintained in stalls, a stall nameplate may be the most appropriate record. This may be made of durable paper or a blackened board on which the cow’s name or number, date bred, date of calving, milk and fat production, feed type, recent health interventions and other information are recorded.

Tattoos may be used in animals’ ears with appropriate tattoo pliers which automatically advance the number tattooed by one for each successive application. Tattoos are hard to read; reading may be assisted by holding a light behind the ear which highlights the darker tattoo. Tattooing on naturally dark skin makes tattoos particularly difficult to read. Photographs and sketches may also be used for animals with distinct colouring which can be easily used by assistants who may not be familiar with individual animals on certain occasions. Brands may be either hot or freeze types. Hot branding is permanent and is easy to read but disfigures the hide of a cow. This has implications both in terms of the value attached to the hide when animals are culled, and to the appearance of the animal during its productive life.

Trends in western countries to minimise unnecessary suffering for domestic animals should be expected to flow to all countries. These would impact heavily on the use of hot branding. Freeze branding, which may involve assistance from a veterinarian or technician requires special equipment and liquid nitrogen or dry ice. It leads to the hair growing from the branded area being a different colour, usually white, which is readily visible. Metal ear tags are a common form of identification. These are clamped on with special application pliers and while apparently permanent may be easily pulled off if animals are caught in thickets. Tags may also be difficult to read. Plastic ear tags, which require their own applicator are produced by various companies and some have proven reasonably durable, particularly under stalled based conditions. Neck chains, neck straps or horn chains with numbered tags have also been used, while ankle tags and tail tags are preferred for milking parlour designs where the head of the animal is not commonly seen.

Identification information is useful to dairy farmers when:

- a sire is to be selected and one wishes to avoid in-breeding
- heifers are evaluated for breeding and superior bulls must be chosen
- evaluating overall herd reproduction and determining the age of heifers at first heat
- knowing the age at which a heifer should be targeted for breeding
- determining whether an animal is an appropriate size for its age
- comparing genetic lines across an area (with other dairy farmers) to determine which animals to cull
- determining which animal should be culled on the basis of age.

**Breeding records**

As the benefits from identification indicate, a farmer with records based on identified cows can improve his breeding management by being able to determine such matters as; the date at which to dry a cow off, knowing when a cow should deliver a calf, highlighting poor insemination or bull services, establishing breeding dates and feeding programmes, identifying calf, sire and dams, and determining the date for pregnancy testing.

Breeding records must be up-to-date and easily accessible. They should be kept in a dry and clean place within the dairy shed in a position which the smallholder passes each day and can easily stop to up-date records.

Breeding records should include:

- the identification of an animal including its birth date
- name of sire and dam.
- heat dates and comments
- calving dates and comments
- earliest breeding date
- service information
- pregnancy examination
- expected calving date
- drying off date
- any additional remarks.

Breeding records are recorded in several forms. At their simplest form this may be a simple addition to the identification plates referred to earlier. In other cases, single page records are maintained in a simple book accessible to veterinarians, AI technicians, extension agents and others concerned with the dairy farm. As the records are useful to such diverse parties, it is helpful for dairy farmers to determine with these persons, the most appropriate system for all of their purposes. Card files, booklets, individual sheets and other forms of recording have all been used successfully although those overall systems seem to work best when farmers in a milk collection area have similar record-keeping systems. This facilitates the easy use of records at individual farms by veterinarians and others servicing a specific area. It also facilitates the addition of milk recording if the system is common to a milk collection or milk factory area.

**Milk production records**

Milk production records help a smallholder determine which animals are bringing down the average yield and therefore income from the herd. The more animals that are kept, the less likely the intuitive approach to individual cow production will be accurate. Once there is knowledge about milk production per cow in terms of the basis of payment for milk (volume or milk solids or fats) then the amount of feed allocated per animal and its cost can be used to determine the viability of maintaining such an animal in the long term. Good milk production records can assist to raise milk production from an individual cow and a herd through specific management for individual animals. It is a powerful management tool for the smallholder and a mechanism for milk quality maintenance by collecting agencies and factories.

Milk production information can be obtained from the smallholder's own records, by using herd improvement association records where such associations exist, or by record keeping systems sponsored by pure-bred cattle associations, where these exist. Smallholders will usually start with a home kept record system. While these have major limitations, the advantage to smallholders is becoming familiar with the reason for keeping such records. In larger herds, good intentions to keep such records often disappear over a period of time. Dairy farmers in developed countries can usually join a testing programme which is large enough to hire persons to maintain records or to assist farmers in maintaining those records. This is a system to which smallholders should strive to belong. Where they do not exist, smallholders can stimulate their formation through co-operatives and milk factories.

In the United States, for example the Dairy Herd Improvement Association has a supervisor visit each farm each month. The supervisor weighs milk from each cow during each milking and samples the milk for butter fat, records any management information required, takes milk samples to the testing laboratory and forwards information to a central computer processing facility. The registry which maintains milk recording information is then accessible by the individual farmer for information about his own herd. A fee is usually levied where breed associations are concerned. Herd improvement associations, on the other hand may not levy significant fees as they operate on a non-profit basis and exist for the mutual benefit of milk producers and processing agencies. In developing countries, smallholders should usually expect to benefit from the establishment of such schemes using some government assistance, even for co-operative and milk factory co-ordinated schemes.

Herd Improvement Associations, where they cover large numbers of herds and animals, can provide the following services to farmers:

- monthly herd reports listing individual cows, milk production and management information
- individual cow slips which documents a cow's milk production over time
- the life-time history of a cow for all information on one single sheet
- the cow's ranking in the herd summary for a range of criteria
- reports concerning sires from across a range of AI sources and bulls
- newsletters of extension information and tips.

**Recording for health**

Calling in a veterinarian to examine animals once they show a health problem is a more common approach than regular veterinary visits. With the use of records, veterinarians can gain additional information about the probable causes of ill health in an individual animal to compensate for lack of familiarity with an individual arrival. Information concerning milk yields, quality of milk, dates of last change of status in reproductive and lactation terms, and other general information is of value in addition to the personal observations of the cow's owner. The reciprocal of having access to this information is that health treatment information is also recorded for individual cows on-farm. Such on-farm recording about the various vaccinations,
treatments and other veterinary interventions forms an individual cow history which increases the probability of future treatments being effective. Some of the information which veterinarians utilise in the Danish dairy industry (Laritsen 1991) include:

- individual animal records of treatment across an entire lifetime
- disease statements - all diseases recorded by all concerned persons for the overall herd
- udder health - graphical representation of udder health of the overall herd in terms of number of cases of mastitis
- individual cow cell count at last milking.

While the objectives of recording for health or for breeding purposes may appear to have developed separately and to have minimal interaction, from a farmer's viewpoint, there are benefits in the short term from a recording service in terms of improved herd and individual cow health, and in the longer term in terms of continued improvement of genetic material.

**Use of the system in the United States**

In the USA, the National Co-operative Dairy Herd Improvement Programme provides an overall testing and recording service. Information on production and management is provided to dairy farmers to assist them in improving their own herd profitability. Data is also useful to breeding groups and to universities and government research programmes. It is funded by fees charged to individual dairy farmers in the data collection process and, in its development phases over several decades relied on government funding. Dairy Herd Improvement organisations operate in 48 states, largely in the form of member co-operatives governed by dairy farmer boards. The Dairy Herd Improvement organisations are represented primarily through the National Dairy Herd Improvement Association which has responsibility for interpreting and enforcing standards and monitoring the quality of services provided to members. Processing is conducted through nine major centres operated by public universities, State Dairy Herd Improvement organisations, milk marketing co-operatives or in some cases privately owned processing centres. The system caters for around five million cows and some miscellaneous goats, representing approximately 45 per cent of the national dairy herd (Giacominin 1991).

The primary purpose for herd recording, through milk or artificial insemination record systems is the genetic improvement of the dairy herd. Other benefits can accrue from using such data, such as herd and individual health management as discussed in a later section.

The genetic evaluation system must provide information to dairy farmers which enables them to choose superior animals and semen on each occasion that a breeding decision is made. For each local situation, the objective in breeding will vary and it is therefore essential that the first step from the farmer's viewpoint be the establishment of the breeding objective. While profit may be the principal objective in many instances, there are a range of variables which should be considered such as the number of lactations expected for an animal, temperament of milking animals (and bulls, if kept), ease of milk let-down, fertility and reproduction factors, weaning rates, and feed and health costs. Each of these factors and others will be of different importance in each situation and individual farmers may do well to assess the relative importance they place on each of these traits. This is an instance where seeking external advice from extension workers may be of significant benefit to individual farmers. The profit function for one particular case was determined as follows (Goddard 1987):

<table>
<thead>
<tr>
<th>Variable</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (corrected for lactation length)</td>
<td>3.14</td>
</tr>
<tr>
<td>Lactation length</td>
<td>1.34</td>
</tr>
<tr>
<td>Days open</td>
<td>-1.68</td>
</tr>
<tr>
<td>Length of herd life</td>
<td>1.38</td>
</tr>
<tr>
<td>Age at first calving</td>
<td>-0.41</td>
</tr>
<tr>
<td>Weight</td>
<td>-1.05</td>
</tr>
<tr>
<td>Temperament</td>
<td>0.87</td>
</tr>
<tr>
<td>Milking speed</td>
<td>0.60</td>
</tr>
<tr>
<td>Health costs</td>
<td>small</td>
</tr>
</tbody>
</table>

These assessments have been done on a herd-wide basis in a developed country and include economic weightings for temperament based on the milk yield which a dairy farmer would be prepared to forego in order to cull a difficult to manage cow. A negative value for body weight for example, reflects higher feed costs to maintain larger animals. Smallholder systems would weight factors differently; for example temperament is more easily managed in the closer contact system of smallholder farms.
Models are developed from group, regional or nationwide information gathered from herd recording systems. Estimated breeding values are determined from assessment of various traits although in practical terms it is necessary to minimise the number of variables considered in such models.

The cost of such approaches needs to be examined in each situation and it is expected that the overall costs in a developing country may not be justifiable. Goddard and Jones (1988) considered the alternative approaches of bi-monthly recording, that is, recording with a simple milk meter and recording heifers only. While accepting that less precise indicators such as these would reduce the accuracy of selection and predictive measures, the saving in recording costs were likely to exceed the financial benefits foregone by the reduced accuracy. While estimated breeding values are useful in overall dairy industry for the development for a new dairy breed in an emerging dairy country in the tropics, individual dairy farmers must be able to justify the increased costs of such recording to themselves in the short term.

References and suggested reading


## Individual Cow Record

- **Cow's name**
- **Identification number**
- **Birthdate**
- **Sire**
- **Maternal GS**
- **Recorder Signature**
- **Dam**
- **Maternal GD**

### Breeding/Preg. Test/Calving

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<th>Calving Sequence</th>
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## Vaccination

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## Disease diagnosis

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## Disease and treatment

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Owner's name ................................ Member ID..................

Address ............................................................................

Province .................................................................
Chapter fifteen
Dairying in integrated farming systems
C. Devendra

Introduction

There are two distinctive features about dairying in integrated systems throughout the developing countries. One is that dairying is a very important money generating component of integrated farming systems. This importance is more apparent especially in small farm systems where diversification is the rule, and production resources have to be used to maximum advantage to generate immediate farm income. Therefore, as fluid milk can be sold daily, and money also generated likewise, farm operations are able to become more flexible and perhaps even stable. In general, these integrated systems are more important in the rural areas, whereas in peri-urban areas, more intensive and specialised units are found in which dairying is a major enterprise.

The second feature relates to the fact that while dairying is most commonly identified with cattle throughout the developing countries, goats are also widely used for milk production. This is especially true in rural areas where goats are not only sold for cash, but also used to enhance rural nutrition. In Vietnam for example, approximately 84 to 89 per cent of all goats milk produced is sold commercially, and the remainder used for family consumption and even feeding pigs (IAS 1995). In Asia, dairying is further extended to include milch buffalo, which make a most important contribution to both rural families and the national economy. In India, about 79 million buffalo produce approximately 55 per cent of the total volume of milk, compared to about 40 per cent from 199 million cattle. Smallholders in South Asia often use both buffalo and cattle together for milk production in order to combine the different butterfat contents.

Integrated farming systems are common throughout the world. They involve several sub-sectors like crops, animals and fish which are used in a mutually reinforcing manner. The interactions of these components are synergistic, and result in greater total effect than the sum of their individual effects (Edwards et al 1988). More specifically, the benefits often result in ecological and economic sustainability.
The rationale for the type, extent and intensity of integrated farming systems is influenced to a very large extent by environmental dictates, notably, rainfall, temperature and elevation, availability of local resources, and market opportunities. Diversification is central to such efforts, and integrated farming systems also have other distinct advantages as follows:

- diversification in the use of production resources
- reduction in, and spread of, socio-economic risks
- involvement of a preponderance of small farms and small farmers
- use of large populations of ruminants (buffalo, cattle, goats and sheep)
- integration of crops (annual and perennial) and animals
- use of animals and crops play multipurpose role
- low input use and traditional systems
- involvement of the three main agro-ecosystems (highlands, semi-arid and arid tropics, and subhumid/humid tropics).

Dairying within these systems is largely influenced by agro-ecological conditions market opportunities and forces, traditions of milk consumption, feed availability, genotype and availability of suitable animal numbers. This chapter discusses the nature of dairy production in integrated systems, contribution to small farm systems, constraints and opportunities for improvement.

**Types of integrated systems**

Two broad categories of integrated farming systems are identified:

1. Systems combining animals and annual cropping:
   - Systems involving non-ruminants, ponds and fish
   - Systems involving ruminants.

2. Systems combining animals and perennial cropping:
   - Systems involving ruminants
   - Systems involving non-ruminants.

In general, systems combining annual crops are more common in irrigated and lowland areas where water is available and enables intensive crop production. Systems combining animals and perennial crops are more common in upland rainfed areas.

Between the two systems, dairying involving mainly cattle and buffalo is very much more common in the first system involving annual cropping. These are the areas which are usually irrigated where intensive cereal cropping is common, and a distinctive market pull exists because of the peri-urban demand for milk. Thus, dairy production is an expanding feature in these situations in which it is integrated with crop cultivation and provides an economic motivation for farming systems. Such systems flourish throughout the developing countries, and examples of these systems are as follows:

- Philippines: rice, maize, mungbean, vegetables, dairy cattle production, pigs
- Indonesia: rice, maize, dairy cattle production
- Thailand: maize, rice, cassava, dairy production
- Vietnam: rice, maize, sweet potatoes, vegetables, pigs, ducks, dairy cattle production
- Pakistan: wheat, maize, potatoes, berseem, dairy buffalo production
- India: pulses, sorghum, wheat, pearl millet, dairy cattle production
Nepal: wheat, maize, finger millet, barley, vegetables, dairy cattle production
Malawi: maize, groundnuts, tobacco, dairy cattle production
Kenya: maize, beans, vegetables, fruits, dairy cattle production
Nigeria: maize, root crops, alley farming, dairy production
Honduras: maize, rice, beans, fruit trees, vegetables, pastures
Colombia: coffee and dairy production
Equador: vegetables, fruits, dairy cattle production
Peru: maize, fruits, beans, pasture, vegetables, root crops, dairy cattle production.

Although dairy production is more commonly integrated with annual crops, mainly cereals, in some countries it is also practised in areas where tree crops are cultivated. Good examples are dairying in coconut growing areas in the Philippines, Sri Lanka and South India, and oil palm and rubber in Malaysia and Indonesia.

In Sri Lanka, a variation that is common in the upland areas is the ‘Kandyan Forest Garden System’ which involves a combination of tree crops, root crops and herbs stratified into large overhanging foliage categories. Cash crops of vegetables, bananas, pepper and coffee are grown to take advantage of the more open canopy in the widely spaced trees. Dairying is very common among the 20 per cent of farmers in the areas in which goats and poultry are also reared. Widely spaced trees also allow for intercropping with grasses, and the use of multipurpose trees as fences such as *Gliricidia* to provide forage for livestock.

### Economic importance of animals

It is important to keep in perspective the economic role of animals in an integrated farming system. There are four broad advantages:

- diversification of resources and reduction in socio-economic risk
- promotion of linkages between system resource components (land, water and crops)
- generation of value-added products (e.g. utilisation of fibrous crop residues to produce meat, milk and fibre), and
- contribution to sustainable agriculture and environmental integrity.

Food production is the primary objective, but the role of animals clearly surpasses this function. Within integrated systems, animals play a particularly vital role, the extent of which is dependent on the type of production system, animal species and scale of the operation. In this context, dairy production is becoming an increasingly important integrated system in many countries, in which this component generates significant, and more importantly, daily cash income, as well as contributing to the improvement of the livelihoods of very poor people and the stability of farm households. It is for these reasons that dairying in the developing countries is considered to be an important instrument of social and economic change, and is identified with rural development (Kurien 1987).

In the state of Gujarat in India for example, Holstein Friesian and Jersey crossbreds are widely being adopted in mixed farming systems. These crosbreds are having a considerable impact: 1.8 times more milk than Desi, Gir and Kankrej cows, acceptance by both tribal and non-tribal farmers in the farming systems, farm income, and employment opportunities (Patil and Udo 1997).

In recent years, dairying in integrated systems has significantly contributed to the development of peri-urban dairy operations through the supply of animals in several countries. Pregnant cows are often brought from the rural areas into peri-urban systems to promote milk production.
Socio-economic benefits of dairying in integrated systems

It is relevant to consider the magnitude of economic benefits from dairying in integrated systems. To reflect this, case studies that give an indication of the contribution by dairying in such systems in various countries, are presented.

Sri Lanka

The economic performance of three farm units of the Mid-Country Livestock Development Centre were assessed over eight years (1985, 1992). The contribution from vegetables, bananas, pepper, coffee, tree crops, dairying, goats and poultry to the gross farm margin were calculated. The results indicated that dairying contributed most to the total gross margin of the 0.2, 0.4 and 0.8 ha units of 31, 63 and 69 per cent respectively, followed by crops (29, 37 and 19 per cent), poultry (22, 0 and 9 per cent), and goats (18, 0 and 3 per cent). The overall ratio of cash income per Sri Lankan rupee spent was 3.2 for dairying, 1.1 for poultry, 4.5 for goats and 9.9 for crops. Dairying and goats proved to be attractive cash earners with a high labour productively and high capital requirement, while manure to improve soil fertility and biogas to replace domestic fuel were important benefits. Poultry did little to improve farm income (de Jong and Ariaratne 1994). Figure 15.1 illustrates the results.

Parallel to this, the financial, technical and economic performance of dairy farming introduced on abandoned marginal tea lands were surveyed in 76 settler farms that received interest free cattle loans between 1984 to 1990, to stimulate crop-livestock farming for gainful self-employment. Dairy cattle were still present on 93 per cent of the project farms with 77 per cent selling milk. Milk production was attractive for farm gross margins of both project (66 per cent) and control (81 per cent) farmers, and contributed significantly to family gross margins by 32 and 40 per cent respectively. Land improvement by livestock was mentioned as a benefit by 64 per cent of the farmers. Crops contributed mainly to subsistence and only marginally to income (de Jong and Ariaratne 1994).

Also in Sri Lanka, the integration of legume-based pasture (Brachiaria milliformis/Pueraria phaseoloides and Gliricidia sepium and Leucaena leucocephala) and dairy cattle, indicated that the coconut palms in the integrated system yielded 17 per cent more nuts and 11 per cent more copra, while maintaining the nutrient status of the palm above the critical level, despite reduced application of fertiliser. Nutrients returned from 73 kg of fresh manure and 30 litres of urine/palm/yr reduced the cost of fertiliser needs by 69 per cent. In regards to the animals, there was sufficient forage to promote 306 to 590 grams per head live weight increase and three to eight litres of milk per day during the first lactation. The integrated system was more sustainable and economically viable than the monoculture system (Liyanage de Silva et al 1993).
India

Economic analysis of different farming systems (one hectare of irrigated land or 1.5 ha of un-irrigated land) indicated that under irrigated conditions, mixed farming with crossbred cows yielded the highest net profit, followed by mixed farming with buffalo, and arable farming. Mixed farming with Hariana cows made a loss (Singh et al 1993).

Comparative productivity and economies of dairy enterprises (mixed farming with three crossbred cows on one hectare of canal irrigated land versus mixed farming with three Murrah buffalo) indicated that mixed farming with crossbred cows under canal-irrigated conditions was more efficient for the utilisation of land, capital, inputs and the labour resources of the farmer (Kumar et al 1994).

Baseline surveys in Gujarat India, indicated that around 75 per cent of rural households kept cattle in the face of under-employment. More particularly, the farm surveys showed that cattle kept mainly for milk, contributed 32 per cent and 20 per cent for tribal and non-tribal ethnic groups respectively (Patil and Udo 1997).

By comparison to cows and buffaloes, lactating goats contributed between 54-68.9 per cent to total farm income through the sale of milk (Deoghare and Bhattacharyya 1993; 1994; Deoghare and Sood 1994). The significance of milk production from goats and the links to food security and livelihoods of the poor has recently been reviewed (Devendra 1996).

Major constraints to dairy production

In most small farm situations, land is a limiting factor, but small farmers try to maximise production through diversification of the available resources and efficient use of low cost inputs. Within an integrated system where dairying is an important component, there are two major constraints to production, firstly the availability of improved genotypes and secondly, feeds and nutrition.
Concerning the availability of improved genotypes, cattle crossbreeding programs in many countries have lacked co-ordination and have been further constrained by problems of infertility, instability of the crossbreeds and inefficient artificial services at the farm level. The level of exotic blood in the crossbreeds, mainly Holstein Friesian, is highly variable, and ranges from 25-75 per cent in small farms. The overriding issue is inadequacy of numbers and their instability, resulting in inability to intensify and expand commercially. Constraints related to feeds and feeding are as follows:

**Feed resources and nutrition**

The availability and quality of feed resources and efficient nutritional management is the principal constraint to dairy production. This was the case in an assessment of livestock research priorities for crop-animal systems in rainfed agro-ecological zones of nine countries in South East Asia (Devendra et al 1997). The problem is also exacerbated by the higher nutrient demand of improved dairy animals, for example Holstein Friesian crossbreeds, for milk production. The feeds available include grasses and forages, crop residues, agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR).

**Priorities for use of AIBP and NCFR**

Priorities for efficient use of both AIBP and NCFR are presented in Table 15.1.

**Intensifying the use of crop residues**

The major research needs for more intensive utilisation of crop residues are as follows (Leng and Devendra 1995):

- identification of economical and appropriate technologies to improve the potential digestibility of crop residues
- development of the most appropriate strategies to enhance rumen function and the means to administer these supplements.
- development of appropriate means of manipulating net rumen microbial growth efficiency.
- identify and/or develop the feed resources to provide by-pass nutrients
- demonstrating to farmers the profitability of the responses to appropriate packages of technologies, and
- provision or assurance post-production facilities for efficient marketing of the products which should have added value wherever possible.

**Table 15.1. Priorities for the utilisation by animals of agro-industrial by-products (AIBP) and non-conventional feed resources (NCFR) in Asia (Devendra 1987).**

<table>
<thead>
<tr>
<th>Feed source</th>
<th>Characteristic</th>
<th>Species</th>
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<tbody>
<tr>
<td>Energy and protein concentrates</td>
<td>High energy</td>
<td>Pigs, poultry, ducks, lactating ruminants</td>
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<tr>
<td>(e.g., rice bran, coconut cake,</td>
<td>High protein</td>
<td>Pigs, ducks, lactating ruminants</td>
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<tr>
<td>soybean meal, poultry litter)</td>
<td>High protein</td>
<td></td>
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<tr>
<td>Good quality crop residues</td>
<td>High energy</td>
<td>Pigs, ruminants 2 (meat and milk),</td>
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<tr>
<td>(e.g., cassava leaves)</td>
<td>High protein</td>
<td>camels and donkeys</td>
</tr>
<tr>
<td>Medium quality crop residues</td>
<td>Medium protein</td>
<td>Ruminants (meat and</td>
</tr>
<tr>
<td>(e.g., sweet potato vines)</td>
<td>Low protein</td>
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### Supplements and supplementation

A variety of supplements exist that can be used for feeding dairy animals. These include oil meals and cakes as well as leguminous tree forages such as *Leucaena* and *Gliricidia*. Purchased concentrates (mainly energy and proteins) are expensive and their use can only be justified in relation to six factors:

- scarcity or inadequacy of dietary nutrients for milk production (quantity and quality)
- plentiful supplies of AIBP and NCFR
- restriction in energy uptake imposed by bulky roughages
- relatively low price of alternative mixed feeds, home grown or purchased concentrates
- increased lactation length and also persistency, and
- increased milk yield where monetary value is greater than the cost of the concentrates required to produce it.

Leguminous forages and the use of multipurpose trees in farming systems (for fuel, fence line, shade, medicants, forage production and sustainability) are underestimated, and need to be more widely used. The beneficial responses and economic benefits for lactating dairy animals has been reviewed (Devendra 1990). Associated with the use of multipurpose trees is alley farming, which is becoming increasingly common. In many parts of Africa, Asia and elsewhere, feed deficits are common, and alley farming systems that use feed or forage crops between hedges of multipurpose trees such as *Leucaena* and *Gliricidia* that are regularly pruned for mulch and/or forage have been successfully developed especially in Nigeria. It is a technology that improves soil fertility, improves crop yields and animal feed shortages, as well as providing fuel for the household.

A recent review of the role of alley farming in African livestock production (Reynolds and Jabbar 1994), indicated that high quality supplementary feed from legume trees, used strategically, could allow milk output to increase by 25 per cent. On smallholder farms, the additional nitrogen in manure from supplemented cattle, returned to maize crops as fertiliser, increased maize yields by one ton per hectare. The return from using *Leucaena* as animal feed was 2.8 times higher than when used as mulch.

### Nutritional strategies

Feeding and nutrition represents the principal constraint to production and strategic intervention is a most important means to increase productivity from goats. The situation has recently been reviewed in depth (Leng and Devendra 1995) and involves the following approaches:

1. **Intensifying the use of crop residues which include:**
   - improvement of potential digestibility
   - strategies to enhance rumen function
   - manipulating net rumen microbial growth
   - provision of by-pass nutrients
   - demonstration of profitable responses
   - ensure post-production facilities for efficient marketing.
2. Enhancing the utilisation and digestibility of straws through alkali treatment.

3. Strategic supplementation.

In view of the immediate benefits associated with improved feeding, several studies in various countries have demonstrated good results and have been reviewed (Devendra 1993). More recent examples are reflected in the results from using Zebu and Shorthorn cattle in Tanzania (Chenost et al 1993), crossbred Malgache Zebu cattle in Madagascar (Chenost 1993) and crossbred Holstein Friesian cattle in Nepal (Shrestha et al 1997).

**Conclusion**

The role of dairy cattle in integrated farming systems is easily overlooked when dairying is examined through western eyes. Nevertheless, smallholders may not consider becoming specialist dairy producers until an assured market and the reliability of income is clear, and most appear to prefer to integrate the enterprise with other agricultural activities. This creates efficiencies in family labour usage, use of residues and farm nutrient recycling. The smallholder views dairy cows as fertiliser producers, power supply for cultivation, companions, users of easily grown or procured fodder, a self replacing crop, sellable assets from time to time, an acceptable livestock enterprise, and various other modes. Dairying in integrated farming systems is therefore a complex enterprise. Potential improvements and increased productivity from this enterprise can only come from a better understanding of the nature and extent of the interactions with the other sub-sectors, like crops and natural resources, economic benefits, as well as the impact on the livelihoods of small farmers and the environment. Research on these aspects provides major challenges for sustainable dairy development and integrated farming systems in the future.

**References and suggested reading**


Deoghare P.K. and Sood S.B. 1994. Income and employment potential of goat rearing on farms in the


Smallholder dairy production integrated with wheat production in Uttar Pradesh, India. Women largely undertake the management of cows and buffaloes.
Smallholder dairy production using Holstein-Friesian crossbred cows integrated with fruit production in Khon Kaen, Thailand.

Dairy production using Holstein-Friesian crossbred cattle on a small farm in the Mekong Delta, Vietnam.
Introduction

Milking is the process of persuading the cow to let down its milk and allow the dairy farmer to remove it for his or her own consumption or for sale. It is therefore not entirely a natural process. The dairy farmer must manipulate the natural process so that he receives the maximum benefit. It is therefore essential that one understands the natural process in order to manipulate it.

This chapter describes the structure of the udder and teats; blood circulation to the udder; nerves which reach the udder; manufacture of milk from precursors in the blood by the udder; the process of milk let-down; the effect of different milking routines on milk production; and means of withdrawing milk from the udder.

Most of these processes or characteristics are the same whether cows live in the tropics or in the freezing climates of North America or Europe. However, there are two obvious and major differences. The first is one of quality. Milk is an excellent substrate for micro-organisms. In hot countries the temperature is ideal for the growth and multiplication of many bacteria. Some of these micro-organisms cause illnesses in humans (pathogens), and many cause the milk to spoil in a variety of ways. This additional challenge of the tropics has implications for smallholder dairy farmers.

The second factor is the breed of cow. In temperate climates, all dairy cattle are different breeds of
European cattle, *Bos taurus*. They have been selectively bred for a variety of milk producing characteristics over hundreds of years. As heat tolerance is not required in temperate climates, these high producing breeds have not been selected for this trait or for tick resistance, both of which the *Bos indicus* of tropical countries have acquired. *Bos indicus* cattle, including, for example, the dairy breeds of the Indian subcontinent, Tharparkars, Sahiwals and Sindhis, have not been selected for dairy characteristics to the same extent as the *Bos taurus* dairy breeds. This is reflected in the dam’s general willingness to release milk without the calf present. *Bos taurus* dairy breeds release milk on demand.

Where cross breeding programmes have been set up to improve heat tolerance and tick resistance of milking cows, such traits of the *Bos indicus* inheritance need to be taken into account.

**Anatomy of the udder**

The cow’s udder is made up of four ‘quarters’. Each quarter is a separate milk-producing gland which secretes milk toward the teat. The udder is packed full of tissue held in place by the skin of the udder wall. The internal tissue is of two broad types. There is the fatty and connective tissue which carry and support the blood, the nerves and lymph on its way to the glandular tissue, which manufactures the milk and stores it between milkings. Size of udder is not a good guide to the amount of milk a cow will produce. A large udder may, in some cases, contain a large proportion of fatty tissue and may therefore not have the potential to produce as much milk as a smaller udder with a higher proportion of glandular tissue.

Unfortunately for dairy farmers it is not possible to tell how much glandular tissue and how much fatty tissue is inside an udder from outside observation.

**Udder support**

The udder is a large organ often weighing over 50 kg, including milk and blood content. It therefore requires strong support. A diagrammatic depiction of the support mechanism is shown in Figure 16.1. There are two sheets of strong, flat ligaments which support the udder. One runs down the middle of the udder separating the left from the right side of the udder. This is called the ‘median suspensory ligament’. Around the sides of the udder is a web of ligaments, which are called the ‘lateral ligaments’. Both sets of ligaments are attached at one end, either to the pelvic bone or to the strong tendons of the abdominal muscles in the pelvic region. At their other ends they join for the full length of the udder. Where they join is easily seen from the outside of the udder. Most cows will have a groove which runs the length of the udder at the place where the two ligaments join. Both halves of the udder are supported by their own ligament network.

![Figure 16.1. Support mechanism of the udder.](http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap16.html#TopOfPage)
When the udder is full of milk, the teats stick out to the sides. This is because the lateral ligaments will not stretch, but the median ligament is elastic, so as the udder fills with milk and becomes heavier the central or median ligament stretches and the teats are pulled out to the side by the inelastic lateral ligaments.

The udder is completely separate from the abdominal cavity except for two narrow passages on either side, through which pass blood and lymph vessels and some nerves. These passages are called the 'inguinal canals.'

**Inside the udder**

As mentioned above the inside of the udder has two main types of tissue: glandular tissue, and connective and fatty tissue. It also contains a system of milk ducts and blood vessels.

A cross section of an udder from top to bottom, through the teats, is represented in Figure 16.2.

At the top the tissue would appear to be quite dense, with no obvious ducts or canals. Further down the udder the tissue would appear more like a sponge, and near the bottom ducts and reservoirs would become quite clear. Just above each teat, a substantial space is obvious. Unlike the simplified diagram the 'gland cistern' is not a simple container, but is branched and convoluted into an irregularly shaped space.

Below the gland cistern is the teat, which contains the 'teat cistern.' At the end of the teat is the small hole through which the milk is drawn by the calf or the dairy farmer. This hole is called the 'teat canal' or the 'streak canal'. The size of the streak canal and the tightness of the circular muscle (or 'sphincter') which surrounds it determines whether the cow will be hard or easy to milk. The characteristics of the streak canal also have a bearing on the ease with which the bacteria which cause mastitis can enter the udder.

![Enlarged scale](image)

**Figure 16.2. Cross-section of an udder at the teat.**

An enlarged representation of an alveolus section is presented in Figure 16.3. This structure has been likened to a bunch of grapes, with all spaces between the stems and the grapes filled with fatty and supporting connective tissue. The large ducts branch into smaller ducts, and these branch again and again into smaller and smaller tubes, like the stems of the bunch. At the end of the smallest ducts, are lobes...
called ‘alveoli.’ These alveoli are like little sacks, inside which the milk is manufactured.

---

**Figure 16.3. Section of an alveolus cell.**

The alveolar cells which form the main structure of the wall, are a single layer of cells that convert raw materials in the blood into milk. The alveoli have a network of cells surrounding them called ‘myoepithelial cells’. As well as these the alveoli are well supplied with a myriad of blood capillaries.

**Blood supply to the udder**

Blood supply to the udder is critical as its constituents are converted to milk. A cow producing 20 litres of milk a day has around 9000 litres of blood circulated through the udder during that 24-hour period.

Blood flows to the udder from a pair of arteries which branch off from the aorta and enter the udder on each side of the cow’s body by way of the inguinal canals. They branch into smaller and smaller vessels until they finish up as the capillaries surrounding the alveoli. The blood returns to the heart by way of two veins. One follows much the same path as the artery which brought the blood to the udder, that is back up through the inguinal canal and along under the spinal cord to the heart. The other vein called the ‘milk vein’ travels under the skin in front of the udder and goes back into the body cavity near the breast bone, then to the heart.

It is sometimes thought that the size of this clearly visible milk vein will give a good indication of how much milk the cow will be capable of producing. But since quite a large proportion of the blood returning to the heart goes by way of an internal vein, this is not a reliable indicator of potential milk production.

**Nerves in the udder**

Most of the nerves in the udder carry sensory messages from the udder to the brain. There are only a few nerves that control functions in the udder. These control blood flow through the arteries by changing the diameter of the blood vessels. While the alveoli are poorly supplied with nerves, the teats are richly endowed.

**Milk secretion and ejection**

Milk secretion is the process of manufacture of milk from the raw materials in the blood by the alveolar cells and the storage of that milk in the cavity of the alveolus. This is a continuous process which only stops when the alveolar cavity is full and the pressure on the alveolar cells inhibits further secretion.

Milk ejection is the process through which milk is released from the alveoli and flows into the ducts, the gland cistern and the teat cistern, where it can be removed by the calf or the human milker.
Milk secretion

Milk secretion is controlled by hormones, unlike some other glands such as the salivary glands. The hormones of major importance are those secreted by the anterior lobe of the pituitary gland. Prolactin and pituitary growth hormone have a direct effect on the action of the alveolar cells. The hormones which control the thyroid and the adrenal glands are also important.

Milk ejection

Unless the cow 'lets down' milk, neither the calf nor the dairy farmer can remove the full yield. Milk secretion takes place continuously. As the cavities of the alveoli fill with milk some of it will pass into the duct system and move down into the gland and teat cisterns. This milk can easily be withdrawn. All the rest of the milk is held in the cavities of the alveoli, and unless forced out, it remains there.

The 'let down' or milk ejection reflex is controlled by hormones. When the calf suckles her mother, or when the milker washes the udder or starts to milk the cow, messages are taken from the nerve endings in the teats to the brain. When the message reaches the brain the rear end of the pituitary gland, the posterior lobe, is set into action. 'Let down' hormone (oxytocin) is released into the blood, it reaches the udder and causes the myoepithelial cells, which surround the alveolus, to contract. Using the analogy of a bunch of grapes, the contraction of the myoepithelial cells acts as a series of hands squeezing the grapes in turn. 'Let down' is an involuntary process.

Oxytocin in the blood does not last for a very long time. Most of it will have disappeared in about two minutes. Once it has gone the myoepithelial cells relax, the alveoli resume their normal shape and as they do so they draw the milk back from the ducts and cisterns into the cavity of the alveolus. From there it cannot be withdrawn until another release of oxytocin causes the milk to be again squeezed from the alveoli. Some cows cannot release oxytocin for the second time for about fifteen minutes, others can do so almost immediately. The average is around seven or eight minutes. It is therefore important that the removal of milk takes place immediately after milk ejection has occurred. If hand milking does not commence immediately after 'let down', milking can turn into a long drawn out process, and if using a milking machine, it may cause injury to the udder by unnecessarily prolonging contact with the machine.

Interfering with milk ejection

Excitement, stress, pain or fear will interrupt the 'let down' process. The hormone adrenaline is released from the adrenal cortex when the cow experiences any uncomfortable situation. Adrenaline completely blocks the action of oxytocin. Therefore, it is not possible to achieve high yields of milk if the cow is milked in a situation where it is likely to be frightened, stressed, hurt or excited.

Milk secretion and milking practices

Milk secretion is a continuous process which takes place in the alveolar cells high in the udder. The rate at which milk is secreted is reasonably constant, and for most cows remains steady for at least 12 hours after milking, and for many will not change for 20 hours. However, milk production records do not show this pattern because of the carryover effect of what is called 'residual milk', that is, milk that cannot be removed from the udder by normal means. Residual milk is generally around 10 to 15 per cent of the yield, and it can be 15 to 20 per cent of the milkfat. There is always some milk that was manufactured since the last milking that will be left in the udder under all practical conditions. The only way to release residual milk is by injection of the hormone oxytocin, and this is only undertaken experimentally or for
veterinary reasons.

As an example, assuming the milk secretion rate for a particular cow is at a rate of one litre per hour, and that this rate does not change up to 16 hours, and the amount of residual milk is 10 per cent. What happens to the apparent rate of milk secretion when the amount that can be removed by hand is measured, when the daytime milkings are eight hours apart and overnight the milkings are 16 hours apart? Over the 16-hour interval 16 litres of milk will have been secreted and there will be 10 per cent residual milk from the previous 8 hours. The calculation below shows how the apparent rate of milk secretion works out.

The relationship between milk secretion and collection is demonstrated below:

**Milking after 16 hours**

| Total milk in the udder | = 16.8 litres |
| Milk withdrawn | = 16.8 minus 1.68 litres (10 per cent residual milk) | = 15.1 litres |
| Apparent secretion rate | = 15.1 divided by 16 | = 0.98 litres per hour |

**Milking after 8 hours**

| Total milk in the udder | = 8 litres plus 1.68 litres (residual 10 per cent of daily total) | = 9.68 litres |
| Milk withdrawn | = 9.68 litres minus 0.97 litres (10 per cent of 9.68) | = 8.71 litres |
| Apparent secretion rate | = 8.71 divided by 8 | = 1.09 litres per hour |

This exercise shows that, without taking account of residual milk, you may be influenced to think that milking at equal intervals has an advantage over more convenient intervals for the farmer. The results of many experiments indicate that the interval used in the example of sixteen hours and then eight hours between milkings is probably the extreme. With some individual cows, it may have exceeded the limit, and production would be lost. However, for the majority of cows, a sixteen-hour milking interval will have little or no effect on milk production. Beyond that though, a significant reduction of milk yield would be expected.

**Frequency of milking**

It is commonly believed that substantial increases in milk yield will be obtained if cows are milked three times daily, instead of twice.

Care must be taken with these claims as some of the information on three times per day milking has come from studies of milk recording information. In this case, individual farmers have selected which cows will be milked three times per day, and it is not unreasonable to believe that farmers select the cows which are the highest producers to milk three times, while the lower producers are only milked twice per day. Differences of 15 to 40 per cent in favour of three times per day milking over twice per day have been reported. When direct experiments have been carried out the difference in favour of three times per day milking has been between five per cent and 15 per cent. Four times a day milking gives a small increase
over three times per day. From the perspective of reducing labour involved in milking, there has been some interest in reducing the number of milkings. However, it appears that milking once per day for the whole lactation reduces yields by about 40 to 50 per cent. Similarly, milking thirteen times per week instead of fourteen, for the whole of the lactation has been found to reduce yields by five to 10 per cent. A much smaller reduction in yield occurs when omitting a milking per week is practised only for the last half of the lactation.

The widely held belief is that cows which are not milked completely at every milking will have reduced milk production. Experiments have shown that this is not strictly accurate. Leaving half a kilogram of milk in the udder (on top of the residual milk) will result in only a reduction in lactation yield of approximately three per cent. However if greater amounts of milk are left in the udder, the reduction in yield will be much greater.

Milking routine

Milking cows to produce the maximum amount of milk follows on from the principles outlined above. Understanding the milk ejection process explains how cows can be conditioned to let down their milk by the actions that make up the milking routine.

To reinforce the conditioned `let down' response the routine followed in the milking shed should be the same every milking. For example, bring the cow into the shed, put it in the stall, give it some feed, wash the udder, and start milking. It is important that the handling (washing) of the udder is the last thing in the routine before milking starts. The other parts of the routine can be in any order which suits the farmer, but they should follow the same pattern at each milking.

Difficulties in conditioning the let down response can arise with some cows, especially when they have a proportion of Bos indicus inheritance. As mentioned earlier the let down response is naturally elicited by the presence of the calf and the calf suckling. With highly selected Bos taurus dairy breeds the presence of the cow's calf is usually not necessary. However, with Bos indicus breeds and Bos indicus crossbreeds, it is sometimes necessary to have the cow's calf nearby before let down can be achieved, and with some individuals it is necessary to let the calf suckle the cow for a short time to get the let down response to occur.

Below are two examples of how milking routine can affect the time taken to milk the cow and the amount of milk produced.

A farmer from Northeast Thailand who had recently started dairying complained that it was taking more than 20 minutes to milk each cow. It was suspected that since the farmer was inexperienced at milking, there would be something wrong with his milking technique. However after visiting the farm and watching the milking process the problem became clear. The farmer was bringing all five cows into the milking shed, giving them some concentrates, washing them all and then milking them. By the time he had milked the first cow, the `let down' on the others was well passed and so he had to go through the motions of milking them, getting very little milk until the cow was ready for a second `let down'. With some of the cows, he believed that he had got all the milk there was and he stopped milking them when there was still maybe half or three quarters of the milk still left in the udder. This meant that the milk production of these cows was reduced significantly.

By merely changing the routine each cow was washed, then immediately milked, the time taken to milk each cow was markedly reduced, and the amount of milk the cows gave increased as well.

Another dairy farm also in Northeast Thailand run by two sisters achieved high levels of production. Two
out of five cows were producing over thirty litres of milk each day. The cows were very well fed and the
milking routine was distinctive. The cows stood in the yard and came up to be milked when they were
called up by name. As each cow came into the milking stall it was fed and then washed all over, the udder
being washed last. Then one sister sat on each side of the cow, and milked together while chatting
constantly. The procedure would be repeated for the next cow, and so on until all five cows were milked.
In this way each cow was milked very quickly, and there was no chance of the `let down' being over
before the milk was all removed. This particular milking routine really suited the cows and they
responded by giving excellent yields.

The milking process

To remove milk from the udder it is necessary to create a pressure differential across the streak canal, so
the milk is forced from the teat cistern. In other words the pressure inside the teat has to be higher than the
pressure outside the teat, before the milk will flow. When a cow is being milked by hand the milker
squeezes the top of the teat between thumb and forefinger thus preventing milk moving back into the
gland cistern, then the teat is squeezed with the other fingers against the palm. This action effectively
raises the pressure inside the teat and the milk flows through the streak canal. The stronger the milker's
hands, the harder the milker can squeeze, creating a larger pressure difference, and faster milking.

With a milking machine, the pressure difference is obtained by reducing the pressure outside the streak
canal, by creating a partial vacuum inside the teat cup. The squeezing of the rubber liner inside the teat
cup does not simulate the milker's hand by increasing the pressure inside the teat. It merely gives the cow
some periodical relief from the negative pressure on the teats. This in itself is important for the cow's
comfort, but it does nothing to the mechanics of withdrawing milk from the udder. The milking machine
is not a faster milker than the best hand milkers, but the machine does not get tired, as even the best hand
milkers do. It is not surprising that the calf is, in fact, the fastest milker of the three. This is partly
explained by the fact that the calf produces the pressure difference across the streak canal, by both
methods. It sucks, producing a lower pressure outside the teat as the milking machine does, and it
squeezes the teat between its tongue and the roof of its mouth, thus increasing the pressure inside the teat
as the hand milker does.

Hygiene

Bacterial contamination of milk and infections in the udder also affect milking. The most common disease
of dairy cows is mastitis. It is most often contracted at milking. Clean surroundings with no mud makes a
huge difference to the number of cows which contract mastitis. As well as this a milking routine which
keeps the udder clean and places a disinfection barrier around the streak canal, is essential to prevent
infection occurring. The disinfection barrier is of key importance because after milking the streak canal
does not close immediately and while open, the udder is vulnerable to infection.

Clean surroundings require an adequate supply of clean water. The problem of mud around the yards and
shed, and a supply of clean water can often be solved by a system to catch and store the water that falls on
the roofs of sheds and other buildings. A good supply of clean water is also the main requirement of
producing milk that is not contaminated with bacteria which will spoil the milk. While detergents, hot
water and disinfectants are important, without an adequate supply of clean water, the job of producing
clean milk is almost impossible.

Suggested reading
Chapter seventeen
Mastitis management
T. Thirapatsakun

Introduction
What is mastitis?
Why mastitis management?
Milk quality concerns
Effects on milk production
Effects on milk composition
Economic importance
Public health significance
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Physical examination
Strip test
Paddle test to detect somatic cells
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Collection of milk samples
Natural defence mechanisms
Teat sphincter and keratin
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Control of environmental mastitis
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Handling mastitis problem herds
Mastitis control in heifers
Implementing herd mastitis control

References and suggested reading
Introduction

Among the challenges of dairy development in the tropics such as breeding improvement, nutrition management, control of infectious, tick-borne, blood and internal parasitic diseases, mastitis is well recognised as being a major problem as it causes a serious wastage and undesirable milk quality. When modern dairy farming in the tropics was first adopted, mastitis was foreshadowed to be an important disease in dairy cattle. Most tropical dairy farmers today have experienced disaster caused by the disease, and can no longer afford its costs in addition to their other burdens.

Control of mastitis requires understanding of its causes and of management techniques which limit the spread of infection. Since dairy farmer knowledge is often lacking help from dairy scientists, extension officers, educators and veterinarians is necessary. It is therefore important that such assistants have adequate knowledge about mastitis control.

Research knowledge regarding mastitis and its control in the tropics is limited. Knowledge from which tropical dairy industries presently benefit, largely originates from extensive research in developed countries. Although environmental and management differences exist between these systems, it is fortunate that the causative agents and infection modes are similar. Therefore, mastitis control methods are essentially similar. The same programme that is effective in pastured herds or large herds maintained in corrals can also be effective in herds located in cold climates where cows are kept in barns throughout most of the year, and in small herds in developing countries in the tropics. Programmes may be fine-tuned to suit the local needs when more locally earned specific knowledge has been accumulated through research. This chapter provides practical information about mastitis management for dairy farmers in the tropics.

What is mastitis?

Mastitis is an inflammation of the udder caused by a variety of micro-organisms, mostly bacteria, that gain access to the interior of the mammary glands through the teat canal. The micro-organisms live on the cow, its udder and in its environment including the floor, faeces, soil, feedstuffs, water, plant material, and milking equipment and utensils. In response to bacterial invasion and multiplication, leukocytes move from the blood stream into milk in order to fight the infection. This constitutes the inflammatory response, which may go unnoticed in the form of subclinical mastitis, or it may be severe enough to be classified as clinical mastitis characterised by physical, chemical, and usually bacteriological changes in the milk and by pathological changes in the mammary tissue. If the infection is not contained by leukocytes or cleared through treatment, chronic mastitis may result. Such an infected quarter may lose up to 25 per cent of milk production and produce only poor quality milk as long as the infection still exists.

More than a hundred types of micro-organisms are known to cause mastitis. These organisms can be grouped as: 1) contagious bacteria: those that are spread from infected quarters to other quarters, such as, \textit{Streptococcus agalactiae} and \textit{Staphylococcus aureus}; 2) environmental bacteria: commonly present in the cow's environment, such as environmental streptococci and coliforms; 3) other common mastitis pathogens: such as the coagulase-negative staphylococci; and 4) uncommon micro-organisms: such as \textit{Pseudomonas aeruginosa}, \textit{Nocardia}, and yeasts. This distinction is of practical importance because different control measures are needed for different groups of micro-organisms. Fortunately, these organisms are normally killed by pasteurisation and thus seldom cause disease in humans unless pasteurisation is faulty or raw milk contaminated with these organisms is consumed.

Most dairy farmers are conscious of clinical mastitis in their herd, but lack a full appreciation of the
prevalence and economic importance of subclinical mastitis. Clinical mastitis is easily recognised and is characterised by visible abnormalities in the udder and/or milk. The subclinical form cannot be detected by visual observation of the cow or milk but it can be identified by conducting tests to detect infecting micro-organisms or the products of inflammation such as somatic cells in milk. For each case of clinical mastitis in a herd population there will usually be 15 to 40 subclinical cases (Philpot and Nickerson 1991), and most clinical cases are preceded by infection at the subclinical level. Subclinical mastitis tends to cause a herd problem, is of long duration, reduces milk production and adversely affects the quality of the milk. It is also important because it constitutes a reservoir of mastitis organisms that may spread to other cows in the herd.

**Why mastitis management?**

Mastitis results in decreased milk production, impairment of milk composition and quality, economic loss, and public health significance. Effectively controlling mastitis will help reverse these problems. Milk production and milk quality will be improved, producers' income will be increased, and the public hazard to health will be reduced.

**Milk quality concerns**

Good quality milk production is one of the main objectives in dairy farming, in either large or small scale farms. This is because milk of good quality is desirable and hence saleable to the processors and acceptable by the consumers. Good quality milk and milk products as measured by consumers is wholesome, of good appearance, good predictable taste and flavour, maintaining original nutritional qualities, safe from harmful micro-organisms and substances, and has a long shelf-life. To produce good quality milk, the producers must be certain that milk comes out not only from disease-free animals but also from healthy udders by using properly sanitised equipment and maintained at its best for appearance, flavour, nutritional values, and free from drugs and chemical residues, with the least possible microbial contamination. Unhealthy udders which are mostly attributed to mastitis, regardless of the causes, definitely produce bad quality milk, either in terms of milk composition or bacterial contamination. Only sound mastitis management can help producers make more money by running, not necessarily a mastitis-free farm, but at least a near mastitis-free farm.

**Effects on milk production**

Reduction in milk yield is an obvious symptom of clinical mastitis. During the first ten weeks of lactation it could be almost twice as much as the average of reduction throughout the whole lactation which is about six per cent (Taponen and Myllys 1995). Reduction in yield in subclinical mastitis depends on the degree of inflammation which can be estimated from the somatic cell count in milk. Significant losses from individual cows and herds have been shown to be associated with elevated somatic cell counts; higher count equals greater loss. The loss of an individual cow increases from six to 30 per cent as cell counts increase from 100,000 to 1,600,000 cells/ml while the loss of the entire herd increases from six to 29 per cent for cell counts from 500,000 to 1,500,000 cells/ml (Philpot and Nickerson 1991).

**Effects on milk composition**

Somatic cell count also reflects the changes which occur in the composition of milk. As the degree of inflammation increases, the chemical composition of milk more closely approaches that of blood because the components filter from the blood circulation into the mammary gland. Table 17.1 shows the effect of subclinical mastitis on various milk components. It indicates that the yield of total solids, butter fat,
solids-non-fat, casein and lactose is reduced substantially while total protein changes only slightly.

**Economic importance**

Mastitis causes economic losses from decreased milk production and increased management costs. Losses from mastitis are twice as much as losses from infertility and reproductive diseases. The largest proportion of the losses results from a direct drop in milk revenues, the non-marketable milk contaminated with antibiotics, decreased milk production which invariably accompanies the infection and premature culling of the animal in many instances. In Thailand, a rough estimate of the annual loss in 1989 was 700 million baht (Thirapatsakun 1989) and in 1998 the annual loss of 1500-2000 million baht is quite probable. This figure is substantiated by an 18 million baht cost of mastitis tubes imported annually.

Losses caused by clinical mastitis include; discarded milk with antibiotic residues; drug and veterinary and possibly laboratory costs; the possible death of an infected animal; culling; udder damage and interruption of breeding improvement programmes.

A formula for calculation of the basic loss due to clinical mastitis per cow has been developed (Thirapatsakun 1989) as follows:

\[
Em = \left[ P + (L \times Kg \times B) \right] M / 4
\]

where:
- \(Em\) = loss due to clinical mastitis
- \(P\) = cow's price
- \(L\) = days no milk delivered
- \(Kg\) = average daily milk production
- \(B\) = price per kg raw milk
- \(M\) = no. of affected quarter(s)

If a cow valued at 28,000 baht, with 300 days in milk, and an average milk production of 10 kg/day at the price 9.00 baht/kg, lost one quarter permanently from mastitis, the overall loss per lactation would be 13,750 baht. The loss would also be 27,500, 41,250 and 55,000 baht for loss of 2, 3 and 4 quarters, respectively.

**Table 17.1. The effect of mastitis on milk components.**

<table>
<thead>
<tr>
<th>Components</th>
<th>Effect of subclinical mastitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>Decreased 3-12%</td>
</tr>
<tr>
<td>Butter fat</td>
<td>Decreased 5-12%</td>
</tr>
<tr>
<td>Solids-not-fat (SNF)</td>
<td>Decreased up to 8%</td>
</tr>
<tr>
<td>Total protein</td>
<td>Decreased slightly</td>
</tr>
<tr>
<td>Casein</td>
<td>Decreased 6-18%</td>
</tr>
<tr>
<td>Lactose</td>
<td>Decreased 5-20%</td>
</tr>
<tr>
<td>Calcium</td>
<td>Decreased</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Decreased</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Decreased</td>
</tr>
<tr>
<td>Potassium</td>
<td>Decreased</td>
</tr>
<tr>
<td>Vitamins</td>
<td>Decreased</td>
</tr>
<tr>
<td>Heat stability and</td>
<td>Reduced</td>
</tr>
<tr>
<td>taste</td>
<td>Decreased curd strength,</td>
</tr>
<tr>
<td>Undesirable Cheese components</td>
<td>fat, and yield</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Plasmin</td>
<td>Increased</td>
</tr>
<tr>
<td>Lipase (breakdown fat)</td>
<td>Increased</td>
</tr>
<tr>
<td>Immunoglobulins</td>
<td>Increased</td>
</tr>
<tr>
<td>Serum albumin</td>
<td>Increased</td>
</tr>
<tr>
<td>Sodium</td>
<td>Increased</td>
</tr>
<tr>
<td>Chloride</td>
<td>Reduced</td>
</tr>
<tr>
<td>Lactose and salt balance</td>
<td></td>
</tr>
</tbody>
</table>


Additionally, there are also treatment (if any) and replacement costs. For a standard treatment cost, a formula was proposed (Thirapatsakun 1989) as follows:

\[ Et = M \left[ C + (Im + In/M)D \right] + \left[ d \times Kg \times B \times n/4 \right] + P \]

where:
- \( Et \) = cost of treatment
- \( M \) = no. of quarter(s) affected
- \( C \) = bacterial culture and sensitivity test
- \( Im \) = intramammary infusion
- \( In \) = systemic injection
- \( D \) = days of treatment
- \( d \) = days milk withheld
- \( Kg \) = normal daily milk production
- \( B \) = price per kg raw milk
- \( n \) = no. of quarter(s) milk being withheld
- \( P \) = miscellaneous expenses

Therefore a cost of 2000 baht overall results from a cow with an average 10 kg daily milk yield and one quarter affected with a mild form of mastitis, needing three day treatment, milk withheld for seven days from 4 quarters costing 200 baht for bacterial culture and sensitivity test, 240 baht for mastitis tubes (40 x 6; baht x milkings), 50 baht for systemic injection, 9.00 baht/kg raw milk price, and 300 baht for miscellaneous expenses, for example, petrol or vet fees.

Much has been said about economic losses due to clinical mastitis. However, the loss which is less obvious but even larger and higher in frequency, is the loss in milk yield and its quality caused by subclinical mastitis. In Thailand, for example, with the recent average figure of somatic cell counts from 800,000 to 1,000,000 cells/ml (Sukrawee personal communication), the estimated loss of 18 per cent (Philpot and Nickerson 1991) based on 1993 national milk production (232,760 ton) onward due to subclinical mastitis would be approximately 3,500,000 baht which would increase along with 17 per cent increase of milk production annually (MAAC 1997).

**Public health significance**

Mastitic milk can also pose a threat to human health. With severe clinical mastitis, gross abnormalities of milk are readily observed and milk is discarded by the producers. Such milk normally would not enter the food chain. But with subclinical mastitic milk or in the case of a small amount of badly infected mastitic...
milk accidentally mixed into bulk milk, changes in milk may be visible. Some mastitic milk carries bacteria that can cause severe human illness. Although pasteurisation is likely to destroy all human pathogens, there is concern when raw milk is consumed or when pasteurisation is faulty. Some strains of *Staphylococcus aureus* may produce heat-resistant enterotoxins which cause serious food poisoning.

Another public health concern regarding mastitis is antibiotic residues in milk. Residues in foods can initiate severe reactions in people allergic to antibiotics and, at low levels, can cause sensitisation of normal individuals and development of antibiotic-resistant strains of bacteria. Compliance with recommended withholding time helps minimise the risk of antibiotic residues in milk and meat which is the producers' responsibility.

**How does mastitis occur?**

Mastitis may be attributed to deficient management, improper milking procedures, faulty milking equipment, inadequate housing and breeding for ever-increasing milk yield. Management and environmental factors also interact, increasing the exposure of cows to mastitis organisms, reducing the cow's natural resistance to the disease, or aiding micro-organisms' entry through the teat canal. Climate, season, herd size, type of housing, nutrition and stress all influence the incidence of mastitis. Additionally, these factors interact with genetic and physiological factors such as stage of lactation, milk yield, milk flow rate, and pregnancy. Management and environmental factors in the majority of dairy farms in the tropics are far from adequate in terms of mastitis control. Control on smaller farms should be no more difficult to control than the larger ones. Cows anywhere in the world rely upon keen observation by owners and herdsmen to maintain management at a high level.

**Detection of mastitis**

Many different cowside and laboratory tests can be used to detect the presence of mastitis.

**Physical examination**

The most frequently used test involves physical examination of the udder. This is accomplished when the udder is being prepared for milking. Quarters that are hot and enlarged will be evident. Thorough examination is best carried out after milking.

**Strip test**

The second most frequently used test is the strip test, which involves stripping the first few streams of milk onto a strip plate or onto the floor in milking parlors. Mastitic milk will show discoloration, clots, or other abnormalities. Milk should never be stripped directly into the hands, nor should it be stripped onto the floor of a stanchion barn where the cows lie at the same place they are milked, as this procedure will aid in the spread of mastitis organisms to other cows or the other quarters. The strip test should be used by dairy farmers prior to each milking to aid in detecting clinical mastitis. Removal of the first milk also stimulates milk let down and shortens the milking period.

**Paddle test to detect somatic cells**

The California Mastitis Test (CMT) and other similar tests are useful in detecting abnormal milk. These tests are basically management tools to aid in identifying cows that may require special attention. The test reagent reacts with somatic cells in milk to form a gel. Reactions are scored according to the amount of
gel formed when milk is mixed with the reagent. Many dairy farmers and veterinarians prefer to use a simplified scoring system as follows: N = Negative (no gelling), S = Suspicious (some gelling), and P = Positive (distinct gelling) (NMC 1987).

A few streams of milk should be discarded before the test is conducted, and results should be recorded for future reference; gel formation is very short lived. The paddle must be rotated gently in a horizontal plane and all reactions read within five to 10 seconds after rotation of the paddle has begun. When this is done, the test is valuable in detecting subclinical infection that might otherwise go undetected. Positive reactions do not always indicate the presence of infection, and therapy should never be initiated solely on the basis of such results.

**Laboratory tests**

Various inflammatory mediators such as somatic cells, serum proteins, enzymes such as NAGase (N-acetyl-\(\beta\)-D-glucosaminidase), and sodium and chloride concentrations may be tested for mastitis, especially the subclinical form. However, one should be extremely cautious comparing results from different materials as the changes in the inflammatory parameters do not necessarily parallel during the course of the inflammatory process. The most accurate way to identify infected cows is to aseptically collect milk samples from individual quarters or composite samples from all four quarters and have them cultured in a laboratory that specialises in mastitis microbiology.

**Collection of milk samples**

The reliability of laboratory culturing is dependent upon the manner in which milk samples are collected, stored, and handled afterward. Milk sample collection should be done aseptically so that the sample contains only pathogenic bacteria derived from the milk compartment of the udder, not from the teat skin or surrounding regions. When quarter milk samples are taken, two or three streams of milk should be discarded, and the teat end scrubbed for a few seconds with cotton balls moistened with 70 per cent alcohol prior to collecting the samples. Teats on the far side of the udder should be sanitised first and near teats last to avoid the latter being touched again by hands or forearms after being sanitised if the far sided teats were to be sanitised last. When teat ends are dry, milk samples should be collected in prelabelled sterile test tubes and closed with caps from near teats first and far teats last and put on ice water or refrigerated until delivered to the laboratory. Milk samples should not be frozen if the somatic cell counting is to be conducted as this destroys the somatic cells.

**Natural defence mechanisms**

Natural defence mechanisms of the udder can be used to our advantage in mastitis control.

**Teat sphincter and keratin**

The first barrier against mastitis-causing organisms is the tissues surrounding the teat canal, particularly the sphincter muscle that keeps the canal closed between milkings. Since the teat canal remains partially dilated for up to two hours after milking, it is recommended that cows be fed at this time to keep them on their feet until the sphincter muscle tightens to reduce the size of the opening. Antibacterial protein and fatty acids containing keratin in the teat canal partially blocks the opening in healthy teats.

**Somatic cells**
Once micro-organisms penetrate the teat canal, the next line of defence encountered is somatic cells in milk. Somatic cells are present at low levels in the absence of infection but rise dramatically when a quarter becomes infected. Approximately 99 per cent are white blood cells. The function of white blood cells is to destroy infecting micro-organisms and to aid in repair of damaged tissue. The other one per cent of cells in milk come from damaged milk-secreting tissues.

Developing countries in the tropics can hardly afford the monthly electronic somatic cell counts used in developed countries. However, other cheaper but less accurate indirect tests for somatic cell counts such as the California Mastitis Test (CMT) or Wisconsin Mastitis Test (WMT) should be used. Above all, emphasis should be made on preventing the entry of micro-organisms into the teat canal by good hygiene and good milking technique.

Antibodies

Antibodies are a very important resistance mechanism because they are specifically directed against certain mastitis causing bacteria, and their concentrations can be increased by vaccination. However, as many different species of bacteria can cause mastitis and most bacterial species that cause mastitis include many immunologically different strains, vaccination against mastitis is rather difficult. Vaccination programmes for controlling mastitis in the tropics have not yet been attempted.

Nutrition

Malnutrition increases susceptibility to infections. As dairy cows are bred to produce more milk, it is difficult to fulfil the nutrition requirements to cope with the production. Marginal nutritional deficiencies are likely to occur. Cows with parturient paresis (milk fever) and ketosis (energy deficiency) or selenium, vitamin E, and copper deficiency have an increased risk of mastitis. Vitamin A and beta-carotene are also needed for the mammary immune system to function properly (Chew 1987).

Control of mastitis

Background problem

Tropical dairy farmers, unaccustomed to paying much attention to the mammary glands, often thought that mastitis would never occur in their farms. However, commercially raising of dairy cattle highlighted the disease. Mastitis management becomes more difficult when some dairy farmers, embarrassed by their knowledge and management deficiency, disguise the truth about the real incidence of mastitis in their herd. The situation is aggravated by inadequate milk tests at reception of the majority of the milk collecting centres.

Many dairy farmers appear hesitant to implement mastitis control programmes because of the inconspicuous nature of the disease and the fact that most are accustomed to living with it. Tropical dairy farmers will have to pay more attention to all the factors associated with teat exposure and resistance to micro-organisms, both during intervals between milkings and at milking time. These factors include housing management, hygiene, nutrition, and stage of lactation, as well as methods used in milk production such as premilking udder preparation, proper milking equipment and technique, and postmilking management, particularly when milking is performed in the same place where the cows live such as in the stanchion barns.

Advisory personnel or extension officers must be equipped with sound knowledge about the disease, having correct understanding about the disease and its control. Furthermore leaders in the dairy industry
having correct understanding about the disease and its control. Furthermore leaders in the dairy industry should agree on common goals and recommendations, and ensure that everyone associated with the dairy industry makes the same recommendations. Otherwise farmers are likely to become confused and may not adopt any new practices.

**Mastitis control strategy**

Mastitis is best viewed as a herd problem rather than an individual cow problem. Unlike other cattle diseases such as brucellosis or tuberculosis, mastitis cannot possibly be eradicated on a large scale. Each individual herd is the unit of control by itself. The level of mastitis in a herd has nothing to do with the level in neighbouring herds. In controlling mastitis on a large scale, the primary need is not for a national mastitis control programme but for a herd mastitis management programme applied nationally.

Controlling mastitis involves a number of steps referred to as a `control programme'. To be acceptable, such a programme must be practical, easy to understand, highly effective in most dairy herds, increase economical returns, reduce new infection, shorten duration of pre-existing infections, provide tangible evidence that clinical mastitis is reduced, and be subject to easy modification as improved methods are developed.

In controlling mastitis, it is necessary that the level of infection in a herd be known to be able to assess seriousness, and sources and risk of spread of the infection. Prevalence of mastitis indicates a level of infection or the proportion of cows or quarters infected with the disease at a given time. The level of infection, clinical or subclinical, varies from farm to farm according to the environment and management factors in each herd. Regular monitoring of each farm is necessary. For practical reasons, the effectiveness of a mastitis control programme is measured by the level of infection, that is, the percent of cows or quarters infected which is dependent upon both the rate of new infections and the duration of each infection. If the rate of infection is reduced, the level of infection will fall, though very slowly. If the duration of infection is effectively shortened, the level of infection will soon be reduced, provided that no new infections occur. To keep mastitis at a low level it is necessary to prevent as many new infections as possible and then shorten the duration of those that do occur and finally eliminate the existing infection.

The Comprehensive Plan of Mastitis Control, designed to reduce the rate of new infections and shorten the duration of infection (Philpot and Nickerson 1991), has been widely adopted and if followed conscientiously on a continuing basis can effectively control mastitis in the vast majority of dairy herds. With some modification, it should be appropriate to apply for mastitis control in the tropics (Table 17.2).

<table>
<thead>
<tr>
<th>Management task</th>
<th>Specific actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milking hygiene</td>
<td>Milk teats that are both clean and dry</td>
</tr>
<tr>
<td>Milking machines</td>
<td>Stable milking vacuum no slipping or squawking of liners shutting off vacuum before removing</td>
</tr>
<tr>
<td>Post-milking teat dipping</td>
<td>Immediately after removing cups full teat immersion not spraying</td>
</tr>
<tr>
<td>Drying off</td>
<td>All quarters of all cows after last milking</td>
</tr>
<tr>
<td>Treatment of clinical cases</td>
<td>Early detection and treatment maintain records</td>
</tr>
<tr>
<td>Culling</td>
<td>Cull chronic cases</td>
</tr>
<tr>
<td>Environment</td>
<td>Clean and dry uncrowded and well ventilated</td>
</tr>
</tbody>
</table>

Table 17.2. *Comprehensive mastitis control.*
Herd replacements

Test new animals before adding to herd check new animals regularly

Recommended milking procedures

Although the cow is usually exposed to the act of milking and associated events for less than 15 minutes a day, this period is a prime time for increased susceptibility to new infections. Correct milking procedures therefore are important, regardless of whether cows are milked by hand in traditional dairying situations or with modern milking machines. Preparation of teats and udders for milking reduces the number of contaminating micro-organisms on teat skin, and stimulates milk let down. Correct teat and udder preparation will reduce microbial contamination of milk, decrease residual milk left in the udder at the end of milking, increase milk yield, decrease milking time, and reduce the spread of contagious and environmental organisms that may cause mastitis and/or reduce milk quality. A summary of recommended milking procedures is as follows:

Provide cows with a clean, stress-free environment

The cows should be milked in an environment that is as clean and sanitary as practical. The milking time should be a consistent routine, and the cow should not be frightened or excited before milking because such stress results in hormones being released into the bloodstream that interfere with normal milk let down and may reduce the cow’s natural resistance to diseases such as mastitis.

Crossbred cows that have hairy udders should be clipped as necessary to remove long hair and to reduce the amount of dirt, manure and bedding that may contaminate milk. Also, the hands of milkers should be thoroughly washed and dried before milking, and hands should be rinsed in a disinfectant solution between cows. This procedure will help to minimise the spread of mastitis organisms from cow to cow.

Check udder and foremilk for mastitis

The presence of clinical mastitis can be detected by using the hand to physically examine the udder and by using a strip cup or plate to examine foremilk before each milking. These procedures aid in detecting hot, hard, and enlarged quarters as well as clotty, stringy, or watery milk. Strip cups and plates should be cleaned and sanitised after each milking to prevent the spread of mastitis organisms. Milk should never be stripped directly into the hand because the procedure spreads organisms from teat to teat and cow to cow.

Wash teats and lower surface of the udder

Correct washing and massaging of the udder sends a signal to the pituitary gland at the base of the brain, which secretes the milk let down hormone, oxytocin, to the bloodstream. This hormone then travels to the udder where it stimulates the muscle cells surrounding milk-secreting tissues to contract and cause milk let down. All teats, as well as the lower udder, should be thoroughly washed, massaged, and dried.

A sanitising solution should be used in a bucket with an individual cloth or paper towel to wash the udder when cows are maintained in stanchion barns. Use of a common cloth or sponge should be avoided because these become grossly contaminated and are almost impossible to sterilise.

Use a premilking teat dip (optional)

Disinfecting teats with a germicidal teat dip before milking is known as predipping; this can reduce the rate of infection with environmental organisms by 50 per cent and a modest reduction in mastitis caused
by contagious micro-organisms. The recommended procedure is to: clean teats, forestrip, predip all teats, wait 20 to 30 seconds for contact time, and thoroughly dry the teats with individual towels to remove germicide residues before applying milking caps.

**Dry teat thoroughly**

Regardless of method used to wash teats and the ventral surface of the udder, it is imperative that surfaces be dried. Single service paper towels are preferred, though individual cloths for each cow can be used if they are washed, sanitised, and dried between milkings. Use of excessive water to wash teats and udders and failure to thoroughly dry the skin, results in water laden with micro-organisms draining down and being drawn into teat cups.

**Attach teat cups within one minute**

Attachment should be done carefully to prevent the entrance of excessive air into the milking system. Maximum internal udder pressure is reached approximately one minute after udder preparation has begun and lasts for about five minutes. Since the majority of cows will milk out in three to five minutes, attachment of teat cups one minute after stimulation has begun makes maximum use of the milk let down hormone oxytocin.

**Adjust milking units**

Milking units should be observed closely while attached to the udder to insure that they are adjusted correctly and to aid in preventing liner slips. It is extremely important that slipping or squawking teat cups be minimised because such occurrences slow down the milking operation and may cause machine-induced infections. If liner slips occur at the same time the liner opens, tiny droplets of milk may be propelled against the end of the teat at high velocity. Such droplets may contain mastitis organisms and may penetrate the teat canal. Since milk flow is reduced near the end of milking when most liner slips occur, the chances of the organisms being flushed out are reduced and an infection of the quarter may result.

**Shut off vacuum before removing teat cups**

The vacuum should always be shut off before teat cups are removed at the end of milking. Never pull the milking unit off the udder while still under vacuum because this practice causes the same problem as squawking teat cup liners and may result in machine-induced infections. A minute or two of overmilking with a properly functioning milking unit does not pose a major risk in terms of mastitis. If a quarter milks out ahead of the other quarters and if the teat cup remains attached to the teat without slipping, it should be left on because careless removal may permit air to enter, which stimulates a linerslip and may result in machine-induced infection via droplet impaction. If there is a probability of slipping on a particular teat, then the cluster should be lifted gently to seal the short milk tube of the liner over the ferrule of the claw to shut off the vacuum before detachment from the teat. Never remove the teat cup while under vacuum.

**Dip teats with an effective teat dip**

The dipping of teats immediately after milking in a safe and effective teat dip is the most important thing a dairy farmer can do to reduce the incidence the rate of new infections. The goal should be to dip the entire surface of the teat that comes into direct contact with the teat cup liner. This postdipping is to aid in controlling contagious mastitis. Teat spraying almost never covers the entire surface of the teat and is not
encouraged. Teat cups should be kept clean and sanitary, but teat dip should never be poured back into the original container as the strength of the used teat dip may be reduced and allow the organisms to survive.

**Disinfect teat cups between cows (optional)**

Teat cup liners are often heavily contaminated with mastitis organisms as a result of milking infected cows and may serve to spread organisms from one cow to another. If the liners are to be disinfected, two teat cups should be dipped at a time, in a disinfectant solution. The solution should be changed when it becomes cloudy. This procedure must be done properly otherwise it may serve to spread mastitis organisms rather than eliminate them.

**Recommendations for milking equipment**

Problems with both milk quality and mastitis can result from improper design, malfunctioning, misused, or an improperly cleaned milking machine. Research in Denmark shows that if milking machines are properly designed, maintained, and used they will account for only about six per cent of all infections of the udder (Philpot and Nickerson 1991).

Milking systems are available in many different designs and sizes to meet the needs and resources of individual dairy farmers. All milking systems have the same basic components. These include: a vacuum system; pulsation system; milk removal system; milk handling system; and an electrical system. With respect to mastitis control, it is the milk removal system and in particular the teat cup liner slips which are associated with milking machine induced infections. Recent research has shown that a problem with liner slips exists if there are more than five to 10 liner slips per 100 cows. Some of the causes have been shown to be: poor cluster alignment; poor liner design; uneven weight distribution cluster; blocked air vent at the claw; and flooded milk lines. Other research has shown that slipping or squawking liners result from interaction of: liner design; cluster weight; vacuum levels; vacuum fluctuations; milking wet teats; absence of hose support arms; overmilking; and teat size.

**Control of contagious mastitis**

The most important contagious organisms are *Staphylococcus aureus* and *Streptococcus agalactiae*, though *Corynebacterium bovis* is also common in many dairy herds. *Mycoplasma bovis* is also highly contagious, but is very rare. The primary reservoirs for these organisms is infected quarters, though *Staphylococcus aureus* readily colonises teat skin and the teat canal, and has also been isolated from the udders of heifers that have never calved. These organisms, with the exception of *Mycoplasma*, are usually controlled quite easily by: good udder hygiene; correct use of good milking machines; dipping teats after milking; and treatment of all quarters of all cows at drying off.

The spread of *Staphylococcus aureus* within a dairy herd can be reduced by: milking first lactation animals before older cows; uninfected cows second; and known infected cows last. The use of vaccines against this organism should be viewed as an adjunct to control programmes described above, rather than as a replacement.

*Streptococcus agalactiae* can be eradicated from a dairy herd within a few months by following a culture and treat programme followed by the ‘Comprehensive plan of mastitis control’ outlined earlier. It is also necessary, that the situation be evaluated by a qualified person prior to detailed procedures for eradicating the micro-organism being implemented.
Control of environmental mastitis

A wide variety of environmental pathogens may cause mastitis. The most important organisms in this group are Streptococcus uberis, Streptococcus dysgalactiae and coliforms such as Escherichia coli and Klebsiella spp. As the name implies, these organisms originate from the environment and control is best achieved by decreasing exposure of the teats to the organisms. This means keeping cows in as clean an environment as possible. Infection with these organisms is higher in housed herds than in pastured herds, when muddy conditions exist, and during the wet season. Organic bedding such as straw, supports the growth of environmental bacteria more than inorganic bedding such as sand or limestone.

Environmental mastitis is associated with a high incidence of clinical mastitis in the herd which may fluctuate according to season. The bacteria isolated from the clinical cases are usually gram negative or Streptococcus uberis. If the mastitis is generally caused by E. coli, sampling of the whole herd is not necessarily of much help, as cases of E. coli mastitis seldom become chronic. The key to solving an E. coli mastitis problem is usually a dry environment. Water use should be kept to a minimum in the barn. Teat dipping and dry cow treatment have no influence on coliform mastitis.

Streptococcus uberis infections often occur during the dry period. The sources of infection are generally the cow and its immediate environment. Antibiotic treatment is not always efficient and chronic cases must therefore be culled. Good hygiene is most essential in the prevention of Streptococcus uberis mastitis.

Klebsiella infections are typically very difficult to treat, and the infected animals usually have to be culled. Before the mastitis problem is found to be caused by Klebsiella, a few cows may already have been lost. A vaccine against coliform mastitis is commercially available in some countries. A heat-killed Escherichia coli J-5 mutant vaccine tested at the University of California, Davis administered subcutaneously at drying off, 30 days later, and again within 14 days of calving can uniquely stimulate antibody production against a wide variety of coliform bacteria, such as Escherichia coli, Klebsiella pneumoniae, and Enterobacter species. The vaccine alone will not eliminate coliform infections from a herd, but if combined with good management practices, will reduce the incidence of new infection.

Control of mastitis caused by other micro-organisms

The opportunistic micro-organisms include over 20 species of Staphylococcus species other than S. aureus (sometimes referred to as coagulase-negative-staphylococci or CNS) and are often the most frequently isolated bacteria in the herd. Infections with these organisms are usually mild and elicit only a slight increase in somatic cell count. The organisms are normally found on healthy teat skin and on the milkers' hands and are thus in an opportunistic position to colonise the teat canal and penetrate to the milk-producing tissues of the udder. Incidence of staphylococcal infections is greatest during the early dry period when the teat skin is not exposed to germicides, so the percentage of quarters infected is high at calving. The use of a postmilking teat dip is the best means of controlling infections by Staphylococcus species. Dry cow therapy will eliminate a high proportion of existing infections at the end of lactation, but new infections in the dry period can be expected.

Other, less common, organisms that may cause mastitis include Pseudomonas aeruginosa, Arcano pyogenes (formerly known as Corynebacterium pyogenes and Actinomyces pyogenes), Nocardia asteroides, Serratia marcescens, Prototheca zopfii, Candida (yeast), and Bacillus spp. Infections by these organisms are usually sporadic and affect only one or a few cows in a herd, but can produce severe clinical symptoms. Pseudomonas aeruginosa, Serratia marcescens, and Nocardia asteroides are generally resistant to most antibiotics and are survivors in certain teat dips. Hand washing with these microorganisms is important.
resistant to most antibiotics and can survive in certain teat dips. Herd outbreaks with these microorganisms are usually traced to contaminated water and poor treatment practices. The organisms are inadvertently placed into an udder by contaminated cannula, syringes, treatment preparation, home-prepared medications and inadequate pretreatment teat end sanitation. Water sources and udder wash hoses should be checked. Milking equipment should be kept in good order and teat end injury should be avoided as lesions provide a site for the growth of all mastitis micro-organisms.

**Role of mastitis therapy**

Despite the use of excellent preventive methods, some new infections still occur. Spontaneous recovery may occur in mild cases while others may require drug therapy. Culling, the other viable alternative for eliminating existing infections, is necessary in the cases of chronic infections that have resisted therapy. Successful antibiotic therapy for intramammary infections involves: drugs reaching all sites of infection in the affected quarters; drugs remaining at adequate therapeutic levels at all sites of infection for an adequate period of time, and killing all infecting micro-organisms.

**Lactation therapy**

Treatment during lactation is indicated only when: cows are infected with *Streptococcus agalactiae*; the herd somatic cell count is 600,000, and when clinical mastitis is present. Cure rates of the treatment depend on types and drug sensitivity of the infecting micro-organisms, and the intramammary conditions. It is advisable that treatment protocol be designed by a consulting veterinarian who will base selection on previous experience in the herd and on clinical signs and environmental circumstances. Drugs should be chosen according to the results from bacteriological diagnoses and sensitivity tests. Response to mastitis treatment should be monitored using appropriate inflammatory indicators such as changes in somatic cell count, protein, enzyme and electrolyte contents of milk. The California Mastitis Test (CMT) which measures the somatic cell count of milk is a simple test that the dairy farmers can also use. The test is rather subjective but its reliability is improved when quarters are compared. One should be aware of possible transmission of infection to other cows or quarters.

In the case of cows that are acutely ill, it may be necessary to administer; milk let down hormone oxytocin; large volumes of electrolytes; products to counteract inflammatory prostaglandins, and other drugs as directed by the herd veterinarian. Frequent milking out of the udder may also aid the animal in recovery because this practice helps to remove infecting organisms and their toxins and rid the udder of cellular debris.

Combination therapy, the procedures in which cows are treated simultaneously in the udder as well as systemically with compatible drugs may result in a significant increase in the concentration of antibiotics in udder tissues than treatment in the quarter alone, thus permitting drugs to reach micro-infections deep within the tissues. Cure rates against the chronic cases can be doubled.

**Dry cow therapy**

Dry cow therapy is the treatment of the udder with intramammary antibiotics at the end of the lactation. Treatment of all quarters of all cows at drying off with long-acting antibiotics is one of the most important components of the `Comprehensive plan for mastitis control`. It is the preferred time to treat subclinical infections. Advantages of dry cow therapy include: the cure rate is higher when treated during lactation; higher concentrations of long-acting antibiotics can be used safely; the incidence of new infections during the dry period is reduced; damaged tissue is allowed to be repaired or redeveloped before freshening; clinical mastitis at freshening is reduced, and drug residues in milk are avoided.
Infected quarters treated at drying off and cured at calving will produce 90 per cent of potential milk production during the next lactation whereas a quarter becoming infected during the dry period or which remains infected from the previous lactation will produce 30 to 40 per cent less milk. Concern about the possibility of routine dry cow therapy increasing the resistance of mastitis micro-organisms to commonly used drugs can be relieved since widespread use of dry cow therapy for more than 25 years showed no evidence of treatment associated resistance to drugs among major or minor mastitis pathogens (Philpot 1997).

The recommended procedure for dry cows is to: bring the cow to the end of lactation; treat in all quarters following the last milking; and reduce energy intake. Udders will fill with milk until a certain hydrostatic pressure level is reached and the milk will then be reabsorbed into the bloodstream. Milk in the udder at drying off is the useful vehicle for transporting drugs to all infected sites throughout the udder. Thus, the cow should not be completely dry when treatments are administered.

**Treatment procedures**

Regardless of the type of treatment used, it is important to follow label directions precisely to avoid drug residues in milk. Treated animals should be clearly identified in some obvious manner and they should be kept separate from untreated animals to aid in preventing their milk from being mixed with milk from untreated animals.

Prior to administering any type of therapy into a quarter, it is imperative that teat ends be thoroughly disinfected by swabbing for a few seconds with a pledge moistened with 70 per cent alcohol. Another procedure that is used by many veterinarians is to dip the teat prior to treatment with a teat dip and then administer the treatment through the dip. If teats are not sanitised before treatment, micro-organisms present on the end of the teat and in the teat canal may be forced into the quarter and may cause more severe mastitis than the one for which the antibiotic was intended.

The method of infusing drugs into the udder is also critically important. For example, forcing cannula all the way through the teat canal may actually force micro-organisms into the quarter. Insertion of the infusion cannula about three millimetres into the teat canal, increases the cure rate and reduces new infection. Most pharmaceutical companies have now designed infusion cannulas to this specification.

**Avoiding drug residues**

To avoid detectable residues in milk it is imperative that label instructions be followed exactly. Special attention should be given to dose levels, routes of administration and withdrawal time. Intramuscular injections, uterine boluses, and antibiotic feed may also produce antibiotic residues in milk with even longer withdrawal period, apart from intramammary infusion. Treated cows should be kept separate and should be clearly marked. Written records should also be kept of all treated cows as this information can help in making cull decisions with chronic cases. Treated animals must not be sold for slaughter until the drug withdrawal time for meat has elapsed.

**Handling mastitis problem herds**

A mastitis problem herd may have a high rate of clinical mastitis, a high somatic cell count indicating a herd problem of subclinical mastitis, a high bacteria count or a combination of the above. Poor milking hygiene, poor environmental hygiene, malfunctioning milking machines, improper milking procedures, and inadequate treatment methods are some of the usual reasons for mastitis problem herds.

The best way to start with a problem herd is by analysing a sample of herd milk in the laboratory.
The best way to start with a problem herd is by analysing a sample of herd milk in the laboratory, employing the recommended procedure (Philpot and Nickerson 1991) which has now been widely adopted. The procedure provides valuable and rapid information about the udder health and hygiene of milk production of an individual herd. The procedure involves three tests: a somatic cell count; a bacterial count (standard plate count), and microbiological culturing on blood agar to identify the types and numbers of different micro-organisms in the sample. Integration of the information obtained from the three tests can then be evaluated by a veterinarian or a trained technician to determine the nature, extent, and likely cause of a herd mastitis problem, and identify a herd hygiene problem as evidenced by improperly cleaned milking equipment, wet milking, contaminated water or poor cooling of milk. The information becomes basically a road map for determining the corrective action that should be taken.

Any herd with a high somatic cell count (500,000-1,000,000) should be considered a problem herd because mastitis will be prevalent. A few streams of foremilk from each quarter should be examined carefully to detect abnormalities. Cows with milk that is visibly abnormal or positive to the CMT should be segregated and the milk withheld from the bulk tank. The quarter milk should also be submitted for somatic cell count and cultured in the laboratory to identify the micro-organism responsible for the infections. This information is valuable for determining whether to treat or cull affected animals, and may help in determining the source of the problems as well as the corrective actions that should be undertaken.

High bacterial count indicates probable existence of mastitis-causing micro-organisms and/or bacterial contamination caused by poor milking hygiene, faulty cleaning or functioning of milking machine, and/or poor cooling of milk. If the number of streptococcal organisms is more than 75 per cent of the total, the source is likely to be infected udders. If the streptococcal count is less than 25 per cent of the total, the cause is likely to be improperly cleaned milking equipment, poor udder preparation (wet milking), or poor cooling of milk (Philpot 1997).

Samples with large numbers of streptococcal bacteria plus large numbers of staphylococci, coliforms, spore formers, and other micro-organisms often indicate a dual problem of infected cows and poor udder preparation (wet milking). A sample with very high staphylococci usually indicates poor cooling of the milk. High staphylococcal counts in herd milk are rarely, if ever, caused by an infected udder alone (Philpot 1997).

High coliform counts often indicate broken teat cup liners, low water temperature when the milking system is washed, milkstone on milk-contact surfaces, and failure to use correct chemicals to clean and sanitise milking equipment. A sample with large numbers of coliforms, staphylococci, and environmental streptococci often indicates faulty cooling of milk.

Above all, the ‘Comprehensive plan of mastitis control’ complemented with the Recommended Milking Procedures outlined earlier are the best set of guidelines for control of mastitis.

**Mastitis control in heifers**

Udder infections among heifers are quite prevalent, even in very young animals and can cause inflammation and tissue damage prior to calving.

Sources of infecting micro-organisms are believed to be: the environment; insects, especially flies; suckling among calves (particularly those fed mastitic milk); and microflora in the mouth and on the skin and haircoat. Management practices such as fly control, using individual calf pens, segregation of pregnant heifers from dry cows can help preventing development of mastitis in heifers.

Strategically treating pregnant heifers with antibiotics at different stages prior to first parturition, reduces prevalence of mastitis during early lactation. In instances where heifers are known to harbour udder
Prevalence of mastitis during early lactation. In instances where heifers are known to harbour udder infections caused by *Staphylococcus aureus*, they should be treated at about eight to 10 weeks prior to calving with a dry cow treatment product. With other types of infections, the preferred strategy is to treat at about seven to 10 days before the expected calving date with a lactating cow product. This practice will eliminate approximately 90 per cent of the infections. Treated heifers will produce 10 per cent more milk than untreated heifers. Extreme caution must be exercised when treating heifers to make certain that teat ends are thoroughly sanitised prior to treatment, and that insertion of the teat cannula is partial.

**Implementing herd mastitis control**

An effective mastitis control programme should be carried out, ideally by a team of veterinarians, laboratory microbiologists, milk plant field representatives or extension officers, milking equipment dealers, and most importantly, the dairy farmers. Extension officers are mainly concerned with environmental aspects and milking techniques and often take milk samples to the laboratory for mastitis diagnosis. Milking equipment dealers should ensure that the machine is properly cleaned, maintained and functioning adequately. The programme should be formulated by the practising veterinarian. Advice and education should be focussed on the dairy farmers who must be enthusiastic and well motivated to ensure the success of the programme.

**Establishing goals**

In the beginning, goals should be realistic and achievable. Higher goals can subsequently be attempted when some confidence is gained. The suggested criteria used for assessing the extent of mastitis problems include: herd milk somatic cell counts; herd milk bacteria counts; proportion of the individual cows with subclinical and clinical infections, and; discarded milk due to clinical mastitis both in terms of percentage of the production and the revenue lost. Ideally an electronic cell counter should be used for somatic cell counting. If this is not available, use of WMT or milk NAGase activity should be encouraged for indirect somatic cell count estimation.

High incidence of clinical mastitis usually results from a major deficiency in management such as an unsanitary milking area, inadequate milking hygiene, faulty milking machine, or purchase of infected cows. Any herd with a somatic cell count above 500,000 is usually considered as a problem herd.

While goals used in developed countries (Table 17.3) are probably unrealistic for most of the tropical dairy herds, they provide an example for long term goals.

**Steps in the control programme**

Initial evaluation of the mastitis situation in the herd should be measured by; interviewing the farmer and taking notes; evaluating the state of health of the whole herd; general herd management including, types of housing, bedding, feeding, manure removal, temperature and humidity; age or parity distribution of cows; milking equipment evaluation including rubberware use; milking practices and hygiene; mastitis treatment; culling rate and reasons; bulk milk cell count, followed by individual cow cell count or individual quarter cell count or equivalent estimates by CMT or WMT or NAGase activity; and existing bacteriological diagnosis from the laboratories.

**Table 17.3. Suggested goals for mastitis management in a dairy herd (NMC 1996).**

<table>
<thead>
<tr>
<th>Mastitis Index</th>
<th>Desirable</th>
<th>Needs improvement</th>
<th>Immediate attention</th>
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</thead>
<tbody>
<tr>
<td>Bulk milk somatic cell count</td>
<td>&lt;200,000</td>
<td>200,000 -</td>
<td>&gt;500,000</td>
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</tbody>
</table>

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap17.html#TopOfPage
(SCC/ml) and WMT equivalent (mm.)

<table>
<thead>
<tr>
<th>Bulk milk bacteria count (Counts/ml)</th>
<th>&lt;10,000</th>
<th>10,000 - 25,000</th>
<th>&gt;25,000</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Proportion of cows with linear SCC score &gt;4 (&gt;200,000 SCC/ml or &gt;6mm. WMT equivalent)</th>
<th>&lt;15%</th>
<th>15% - 25%</th>
<th>&gt;25%</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Clinical mastitis incidence (% cows/month)</th>
<th>&lt;2%</th>
<th>2% - 5%</th>
<th>&gt;5%</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Discarded milk due to clinical mastitis (% of production)</th>
<th>&lt;0.5%</th>
<th>0.5% - 1.5%</th>
<th>&gt;1.5%</th>
</tr>
</thead>
</table>

When infection prevalence for a herd is determined, attention must be paid to the quality of the microbiological samples. Aseptically taking of quarter samples from the whole herd is a laborious operation. Sampling should thus be planned and care exercised when sending the samples with necessary information to the laboratory. To cut costs, the microbiological examination may be conducted only on those quarters, which are inflamed. Dry and periparturient heifers may be included in the study for more reliable results. At pre and post partum, the values of the inflammation indicators are always high and comparison of the quarters is then critical.

Disagreements between bacteriological tests and tests detecting inflammatory changes in milk are often encountered. Several reasons for these include: antibacterial factors in milk which prevent outgrowth of bacteria; there are so few bacteria that they cannot be isolated in the small volume cultured; the laboratory methods are not relevant for all types of microbes associated with mastitis; the inflammation is caused by udder trauma or teat injuries; the bacteria have died but the toxins released from them maintain the inflammatory response, and/or inflammatory reaction disappears more slowly after bacteria have been eliminated.

The results from the initial evaluation of mastitis situation should reveal whether the mastitis is environmental or contagious. Appropriate sanitation measured described earlier should then be applied accordingly. The producers must be realise that evidence of progress will often require several months and progress towards the goals established should be monitored on a regular basis. This will help maintain motivation for the programme as well as identify the areas where the programme may have to be re-evaluated. A suggested schedule for monitoring the udder health of a herd is presented in Table 17.4.

A mastitis control programme, even when successful, requires follow-up. Bulk milk somatic cell count or indirect somatic cell estimates is a basic means for permanent monitoring of udder health. Inflammation and infection percentages on a cow and quarter basis are useful tools in addition to other health and management reports. Ultimately, success of a mastitis control programme depends on active participation of all parties involved. The dairy farmers or farm personnel must appreciate the importance of all elements of the control programme. Emphasis should be made on positive reinforcement of goals and profit to be received. Inclusion of all the parties involved in the mastitis control team and recognition for an effort that results in success should be part of the plan. The link to record keeping as part of herd recording schemes should also be recognised.

Table 17.4. Example of a monitoring schedule for a herd mastitis control programme (NMC 1996).

<table>
<thead>
<tr>
<th>Mastitis factor</th>
<th>Initial visit</th>
<th>Monthly</th>
<th>Semi-annually</th>
<th>Annually</th>
</tr>
</thead>
</table>

http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap17.html#TopOfPage
<table>
<thead>
<tr>
<th>Mastitis Factor</th>
<th>Frequency</th>
<th>Frequency</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm facilities</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Milking hygiene/techniques/ teat dip programme</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Milking equipment operation</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rubberware use-hose, liners, etc.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bulk tank and individual cow SCC records</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Culture of clinical mastitis cases and suspect cows</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Review of clinical mastitis and treatment log</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Review of nutrition programme and incidence of other diseases</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

NB: Changes in facilities or udder hygiene practices may require more frequent monitoring.

**References and suggested reading**


Philpot W.N. 1997. Quality milk production and mastitis control. *A comprehensive manuscript to be used as a basis for seminars and workshops*. Philpot and Associates International, Inc. LA, USA.


http://www.ilri.org/InfoServ/Webpub/fulldocs/SmHDairy/chap17.html#TopOfPage


Benefit from mastitis control.

Sources and transmission routes of different mastitis pathogens
Mastitis is the end result of the interaction of environmental, management and cow’s physiological factors.

Local defence mechanism.
The Recommended Milking Procedures.

The comprehensive plan of mastitis control.
Herdsman, advisory personnel, laboratory microbiologist and the herd veterinarian comprise a mastitis control team.
Chapter eighteen
Processed milk products
B.K. Ganguly, P. Bandopadhyay and S. Kumar

Introduction

Milk producers in the tropics apply their ingenuity to cope with climatic and logistical adversities. Being a subsidiary occupation, the average milk producer produces in small quantities. The market is not always within easy reach for delivering fresh raw milk and local processors, if any exist, are constrained to take milk in excess of processing ability as they may be plagued by problems like power failure or transport breakdown. Producers, therefore, have adopted, over the generations, a variety of methods to minimise the loss in value of fat and SNF (solids-not-fat) in liquid milk. The products developed, either for direct consumption or as a base material may have some local variations, in terms of additives, but follow certain fundamental rules of preservation and conservation through, heat desiccation, fermentation, coagulation and clarification. These rules are followed in an effort to recover the total solids to the maximum extent, but take place through processes and technologies which shock modern standards but remain adequate and appropriate to local situations, resources and food-habits. The processors, similarly, adopt small-scale processing technology which is adequate to process limited marketable surpluses of an area, often in the form of a chiller or a bulk cooler, as independent units to cater to the local demand for liquid milk or as feeders to bigger units of the area. As for small-scale processing, it is believed that `it is in fact possible to manufacture the highest quality dairy foods with extremely simple tools and means. It is also true that most dairy foods can be made with the help of relatively few basic processes provided that the manufacturer has the necessary skills and experiences. Complicated machinery and sophisticated processing methods have not been invented to make better dairy products, but to save labour and nothing else' (Bachman 1987).

Preservation and processing at household level

In most of the tropical countries, a fraction of the total milk production enters the formal processing channel for reasons described above. In India, for example, even after nearly three decades of organised milk procurement and market intervention under the Operation Flood programme, of the estimated 30 per cent of the total production which is marketed by the village producers (after meeting the local consumption needs, of both the producers and the non-producers), only 35 per cent is collected by the organised processing sector and the rest by the traders of all hues. According to another estimate, 28 per cent of total production is converted into ghee and another 20 per cent into milk products, such as dahi.
(curd), khoa (dehydrated milk) and a variety of milk-sweets, to enhance shelf-life (Gupta 1997). The villagers try to conserve milk in its freshness, before it becomes sour which makes possible better recovery of milk solids in the products that are made. Much Indian milk production is seasonal in character as nearly half the production is by buffalo which are seasonal calvers. Seasonal surpluses are converted into the above products for which there is a premium in India. The pattern is much the same in Pakistan, Bangladesh, Nepal and Sri Lanka. Figure 18.1 depicts a generalised flow of milk from the producer to the consumers and Figure 18.2 illustrates the prevailing processes of conservation in the Indian sub-continent.

However, Operation Flood provided the Indian disorganised milk producers (the majority being landless or small/marginal holders) in distant and remote villages, with a ready market for their produce year-round and at remunerative prices. This encouraged them to produce and sell more liquid milk. Village-level primary co-operatives collect milk from their members and transported it to the District Union's modern dairy plant, unless local circumstances demand intermediate chilling or cooling facilities, for processing into a variety of milk and milk products. Introduction of refrigerated road and rail milk tankers make collection and haulage of liquid milk over long distances easier. The impact of providing access to the market is evident from the steady increase in milk procurement under Operation Flood. In 1970-71 it was 0.5 million litres a day and increased to 12 million litres a day in 1996-97. Expansion in the organised processing and marketing fields had a similar effect on smallholders participation in dairying in Kenya where, in addition to co-operative creameries, rural separating centres, and where suitable, milk cooling and collection centres, were set up for cream production to which local farmers supply their milk even in such small quantities as half a gallon (Kenya National Dairy Committee 1966; Owiro 1980; Brumby and Gryseels 1984).

In some other countries, consumption demand for sour milk has eased problems of fresh milk marketing. In northern Nigeria most of the milk is locally consumed, either fresh or sour with a relatively small fraction in the form of local cheese (Natural Resources and Research 1966). In Kaduna, 70 per cent of the town's surveyed households consumed only nono (sour milk) not fresh milk, because it sours rapidly in hot weather. Nono, the most preferred milk-type product, is made from skimmed milk and usually sold with fura (doughy patties of sorghum or millet mixed with spices and sugar). Lamudam or kindirmo (yoghurt, more often found in remote rural areas) is thicker than nono and made from whole milk. Cucu or wara is a soft, wet, feta-type cheese made from whole milk. This is sold in small cones, sometimes fresh, but more often fried. Markets also exist for Nebbam or Man shanu which is a local butter (Jansen 1992).
Figure 18.1. Milk movement scenario in the Indian sub-continent.
In Zimbabwe, sour milk forms an important part of the traditional diet, fresh milk is seldom drunk alone. Often naturally soured, the milk coagulates to produce a thick curd called amasi. This is often eaten with Sadza, a thick maize porridge (Henson 1992). In semi-arid Borana plateau of Ethiopia, milk is typically stored to produce ititu or irgo (in Amharic) which is a generic term for either (1) short-term (five day) fermented milk for consumption or making butter (2) longer-term (up to 90 days) fermented milk particularly kept for guests. They also make ghee which can be stored for up to three years. The household processing system can process from a low of about two litres at a time to 100 to 500 litres of

Figure 18.2. Traditional Indian milk products.
processed milk products

household processing system can process from a low of about two litres at a time to 100 to 500 litres of fresh milk, in batches of up to 15 litres. A key to dairy profitability is the extent of fat recovery. A review of milk separation by traditional hand churning, a wooden paddle agitator and a centrifugal separator suggests that the latter gave the best fat recovery but is too costly for small farmers and would be profitable for production of more than 12 litres a day all year round. This would be appropriate for some co-operatives and larger farmers. In Ethiopia's informal system, a smallholder sells surplus supplies to neighbours or in the local market, either as liquid milk or in the form of butter or a cottage-type cheese called ayib. In the highlands of Ethiopia, milk produced by smallholders is used for family consumption and the production of butter and ayib. For butter-making, milk is collected over a period of three or four days in a clay pot. When the milk has soured and sufficient milk has been collected, the clay pot is shaken back and forth, for about two to three hours, depending upon such factors as temperature, quantity and fat content and the acidity of milk. This continues until butter granules are formed.

An innovation developed by the International Livestock Research Institute, formerly the International Livestock Centre for Africa, modified a wooden internal agitator that can be fitted to the usual clay pot, to reduce churning time from an average of 139 minutes to an average of 57 minutes (59 churnings) while reducing the average fat content of the buttermilk from 1.1 per cent to 0.36 per cent. In these processes, residual buttermilk is heated, precipitating the casein and some of the remaining fat, and the coagulated fat and protein is separated from the whey to produce ayib. The price of ayib is about one-seventh that of butter. The monetary advantage of extracting the maximum amount of fat from milk and converting it into butter is apparent (Coppock et al 1992; O'Connor 1992; Shapiro et al 1992). In Bamako, Mali, surveyed urban households were reported to be consuming Sirime (ghee) and sour milk, sweetened or otherwise. In Debre Zeit, Ethiopia, because of availability of fresh milk in the majority of the rural households, only two per cent of smallholders sold fresh milk. Butter, used in rural areas for cosmetic and cooking purposes, is sold by almost 67 per cent of smallholders. About 64 per cent of the smallholders consumed all the cheese they produced and the remaining 36 per cent consumed and sold the produced cheese to different extents. Ghee has a considerably long shelf-life than butter but customers prefer to buy butter and make their own ghee. Spices may also be added to butter to improve its shelf-life but this method is usually confined to butter for use by smallholders. Even when slightly rancid, butter still has a market value. Urban consumers of highland origin use butter for making traditional Wots that are eaten with bread-like Injera made from Teff (Eragrostis tef). A degree of rancidity is actually desired to improve the flavour of wot (Coppock et al 1992; O'Connor 1992). In Madagascar, depending on the region (southern Madagascar has a tradition of curdled milk consumption) and on consumer demand, producers deliver either fresh or curdled milk. When direct sales to consumers are not possible, producers resort to middlemen which include cycling milkmen, small-scale butter and cheese producers, collection centres and dairy plants (Ranaivoson 1992). In northern Tanzania, 57 per cent of the milk protein consumed was in the form of fermented milk (Shapiro et al 1992). In the rural areas of Uganda, a certain amount of ghee production was reported, mainly for household consumption or local trading (Ministry of Animal Husbandry 1966).

Small-scale processing units

Milk must reach a cooling facility or processing plant within two to five hours of milking, or chemical changes occur that make it unsuitable for processing. In arid and semi-arid regions of Africa and the Indian sub-continent, the amount of milk available from farms within two to five hours of any point is not likely to be sufficient for any but small plants. In some parts of Kenya, the amount of milk that can reach commercial factories falls by as much as 20-30 per cent during the wet season because of difficulties with roads (Shapiro et al 1992). In Palestine, it was observed that farmers who comprise 40 per cent of the population are often left with milk production which they are unable to send for processing because of the
absence of a transport and processing infrastructure. In India, co-operative milk plants in the low-lying Gangetic plains are unable to procure milk from many village societies in the rainy season as floods cut off roads. In southern Chile, it was observed that, some dairy farms could not deliver milk in winter due to poor road conditions which affected the operations of the processing plants, with volume of reception showing seasonal fluctuations in a ratio as high as 1:5 (Guillermo 1966).

Thus, small scale processing becomes appropriate in situations where transportation is a constraint, primary production is dispersed, quantity of marketed surplus is limited or immediate neighbourhood demand is low. Since such plants process the milk in the production area itself, they have lower transportation/handling costs than big collectors and provide better returns to the producer by value additions. An added advantage is that when the power fails, alternative methods employing manual labour are used to save the milk and thus reduce the risk of wastage. Requirements of lower levels of energy, skill, maintenance and repair also have a positive impact on local milk production. Cooling centres are reported to have a positive impact not only in providing access to marketing but also making possible more frequent milk collection. A small-scale plant near a small town in Northern India was reported to be processing 1500 kg of milk a day, using simple methods that are mostly hand operated and produce pasteurised milk, sweetened condensed milk, fresh butter, ghee, cheeses and cream caramels (Shapiro et al 1992). In Peru, setting up of rural cheese plants in distant villages helped improve milk quality owing to shortened distance between producers and the plant. In Peru and Ecuador, 60 rural cheese factories have been established at a cost of US$ 2000 in locally made equipment, US$ 1000 for furbishing buildings and US$ 100 as working capital. Simple cheese technology is available in manuals. The Netherlands has supported cheese making in parastatal farms in Tanzania and Sri Lanka and at the co-operative level in Colombia (de Jong 1966). In Ecuador, Cheese Co-operatives were formed in areas not reached by middlemen for milk collection and where farmers could collect, within a three km radius, at least a daily quantity of 300 litres of milk (de Jong 1966). In Afghanistan, small processing plants collecting milk within a radius of maximum of two hours of transportation time have helped collection of good quality milk without cooling. It proved to be easier to build a second processing centre than to centralise milk processing with the help of expensive and unreliable chilling centres (Shapiro et al 1992). Alternatively, as in East Africa, a series of cooling facilities collect producers' milk and despatch it to a larger processing plant. But such a system comes under stress when the cooling facilities or transport to the plant fails and when the large plant itself has problems with machinery, power or inputs such as packing materials (Shapiro et al 1992).

In Africa, small-scale processing could be extended to traditional products such as sour milk, ghee and white cheese in brine, for which the local population has the skills and for which there are local markets. The cheese industry in Sudan's White Nile Province specialises in making soft white cheese using methods that were introduced at the beginning of this century. Usually one factory serves one village, handling a daily average of 275 litres of fresh milk, operated by unskilled workers except for the head worker. There were two factories in 1935, increasing to 70 in 1975. Most of their output is sold in Khartoum and other cities (Shapiro et al 1992). However, small-scale decentralised processing has certain dis-economies of scale. Processing of less than 2000 litres would not be viable, and product quality may differ from plant to plant. In Tanzania, small processors need foreign exchange to obtain inputs such as rennets and starter cultures (Kurwijila 1992).

To overcome the problem of low capacity utilisation due to low volumes or seasonal supplies, it is suggested that dairy plants could make use of local fruit juices and vegetable extracts, as they do in Asia. `Vegetable milks' could supplement animal milk during the dry season when animal milk is in short supply. Vegetable oils could be mixed with milk to produce a high-calorie, low-cost food. Tropical fruit juices and bean extracts could be used to flavour and acidify milk to produce a high-protein, high-vitamin food. As one researcher observed, `One can explore a great variety of possibilities as soon as one accepts that milk is not the only raw material that can be processed in a dairy' (Bachman 1987).
Traditional milk conservation and processing practices in the Indian subcontinent

Because of the generally prevailing unorganised transport, processing and marketing facilities, the people of the tropical countries have mastered the art of conserving or processing the limited quantity of milk they produce. This section illustrates their ingenuity by narrating the household and small-scale processes prevailing in the Indian sub-continent, countries which share common food-habits and preferences.

Indigenous dairy products of the Indian sub-continent could be broadly classified into the following four categories:

1. Heat desiccated/unfermented concentrated whole milk products
2. Fermented indigenous products
3. Coagulated indigenous dairy products, and
4. Clarified butter fat indigenous dairy products (Srinivasan 1964; Rangappa and Acharya 1974; Sukumar 1980).

Heat-desiccated/unfermented/concentrated whole milk products

Khoa (alternatively called mava, khava or palghoa), is a partially dehydrated whole milk product, prepared in a batch of four to six litres in a traditional open shallow pan over a direct fire, by continuous heating and manual stirring-cum-scraping until it reaches a semi solid (doughy) consistency. Pan-contents, khoa-pat, are removed from the fire and worked into a solid mass of different grades of texture (smooth, homogeneous, granular), consistency (thick, sticky) and moisture (31-44 per cent), depending on the type of use it would be put to for making a final product. Three grades of commercial khoa are made:

1. **Pindi khoa**: 21-26 per cent fat, 31-33 per cent moisture
2. **Dhap khoa**: 20-23 per cent fat, 37-44 per cent moisture
3. **Danedar khoa**: 20-25 per cent fat, 35-40 per cent moisture.

The shelf-life of khoa is two to four days under ambient conditions and three weeks under refrigerated conditions. Traditionally, khoa-pats move from village to towns wrapped in leaves and put in bamboo baskets. The shelf-life can be enhanced by using vegetable parchment paper wrappers, plastic (polyethylene) film bags/pouches, laminated (preferably aluminium coated) pouches, tin plates, or cans, in pack sizes varying from 0.5 (or even less) to 1.0 kg. Khoa contains fairly large quantities of muscle building proteins, bone-forming minerals and energy-giving fat and lactose. It is also expected to retain most of the fat-soluble vitamins A and D, and also fairly large quantities of water soluble B vitamins contained in the original milk. Additives to sweetmeats further increase the calorific value of the product. Using cereals, wheat flour, sugar, flavours and other additives, depending upon the local preferences, a wide range of milk sweets/confections/delicacies are made from khoa, on a small-scale and commercial basis:

- **Gulabjamun**: Balls prepared by kneading pindi khoa as base material with additives like refined wheat flour, semolina and baking powder followed by deep frying in cooking medium and further dipping in a sugar syrup.
- **Burfi:** Khoa based sweet, prepared by heating khoa on medium heat, topped by nuts such as pistachio, cardamom or a layer of chocolate.
- **Kalakand:** Prepared from Danedar Khoa, with typical granular texture and added aromatic spices.
- **Peda:** Ball shaped (top and bottom flattened), prepared from dhap khoa, topped with nuts.

**Technological innovations in Khoa-making**

The primitive process of khoa making in mild steel shallow open pans has been scaled up by different semi-continuous and continuous machines which are used in places where the quantity of milk is sufficiently large for khoa making. A semi-continuous khoa making machine was developed by Banerjee et al. in 1976. The plant consisted of a scraped surface heat exchanger and two open semi-jacketed pans with reciprocating spring loaded scrapers. The scraper adjusting mechanism was developed by Sawhney et al in 1980 providing a semi-jacket, shallow open pan and using a swinging hanger type scraper for stirring during the desiccation process. The Conthern-Convap System developed by Alfa-Laval has also been used for manufacture of khoa. A conical vat machine has also recently been developed. The latest innovation is the development of an inclined scraped surface heat exchanger for continuous khoa-making by National Dairy Development Board (NDDB; Punjrath et al 1990). The plant comprises a balance tank, a positive displacement pump and an Inclined Scraped Surface Heat Exchanger (ISSHE). Milk concentrate is used as feed. The sensory characteristic of khoa prepared by ISSHE is similar to those of the traditional product and the chemical composition and rheological properties of khoa maintain uniformity during continuous operation. ISSHE is compact and simple and is being used on a regular basis.

**Technological innovations in Gulabjamun manufacture**

The continuous process line developed by the NDDB, and being used by co-operative dairies in India, for large-scale manufacture, comprises of dough formation, portioning, shaping, frying, sugar syrup soaking, cup filling and sealing.

**Kheer or Basundi** is a cereal-based heat desiccated traditional dairy product, prepared by partial dehydration of whole milk in a traditional open shallow pan over a direct fire, together with sugar and usually rice or occasionally semolina. Consumed directly as a dessert, it contains all the solids of milk in an approximate twofold concentration plus additional sugar, with high food and nutritive value. Additives increase the calorific value of the product (its biological value is 77 and digestibility is 97 per cent). On an average it contains 67.02 per cent moisture, 7.83 per cent fat, 6.34 per cent protein, 8.45 per cent lactose, 1.41 per cent ash and 8.95 per cent sugar. Its average shelf-life, two to three days at 37_C and 10 to 15 days at 4_C, can be increased significantly by addition of nicin to the hot product, at the end of manufacturing process and before packaging.

**Rabri** is a concentrated, sweetened whole milk product, containing several layers of clotted cream. While the milk is slowly evaporated, without being stirred, at simmering temperature in a traditional open shallow pan over an open fire, pieces of skin which form on the surface of the milk are continuously broken up and moved to the cooler parts of the pan. Sugar is added when the volume of milk has been considerably reduced, layers of clotted cream are immersed in the mixture and the finished product is obtained by heating the whole mass for a short period. It contains all the milk solids in an approximately five-fold concentration, with additional sugar. Consumed directly, it has a high food and nutritive value, with approximately 20 per cent fat, 10 per cent protein, 17 per cent lactose, 3 per cent ash, 20 per cent sugar and 30 per cent moisture.

**Malai** is usually made by simmering large quantities of milk (about 10 kg) until a thick layer of milk fat
and coagulated protein forms on the surface. This is skimmed off with a flat ladle and laid aside to cool. The process is repeated twice, when most of the fat has been removed. The product is smooth and white in appearance, tastes like clotted cream and makes up about 20-25 per cent of milk. It is sold and consumed without any addition of sugar.

**Kulfi** is a heat desiccated frozen milk product (indigenous ice cream). While the milk is boiling, sugar is added, the product is concentrated at a ratio of approximately 2:1. Malai, crushed nuts and flavouring (commonly rose or vanilla) is added to the cooled concentrate, the mix is placed in moulds (triangular, conical or cylindrical) of various capacities made of galvanised iron sheets. The moulds are closed on top by placing a small disc over them, the edges made air-tight with wheat dough (modern moulds are made of plastic, generally conical in shape with screw-cap plastic tops) and the moulds are frozen in a large earthen vessel containing a mixture of ice and salt (1:1). A similar product is malai-ka-baraf, prepared by freezing a mixture of malai, sugar, nuts and essence. The product is plastic in nature, with a crunchy texture and delicate nutty, caramel flavour.

**Khurchan** is a concentrated, sweetened whole milk product prepared in a traditional open pan by simmering the milk without stirring so as to allow for simultaneous formation of a thick creamy layer of skin on the surface of the milk and slow evaporation of water. Sugar is added to the concentrate followed by a thorough mixing of the product. Average composition (Gupta and Rao 1992) is 23.6 per cent fat, 15.4 per cent protein, 14.9 per cent lactose, 15.2 per cent sugar, 3.0 per cent ash and 27.9 per cent moisture. It contains all the milk solids in an approximately five-fold concentration, together with an addition of sugar, so its food and nutritive value is very high.

**Fermented products**

Indian households partially extend the life of milk from 12 to 24 hours by simple heat treatment which destroys most microflora. Temperatures of 20-40_C in the warm parts of the year are most favourable for the growth of micro-organisms which bring about spoilage of milk within a few hours of milking. So the simplest way of preserving milk for human consumption in a tropical country is to allow it to sour which checks putrefactive changes while giving the milk an acid taste which is particularly refreshing in a hot climate. A variety of fermented milk products are made and consumed in the Indian sub-continent.

**Dahi** (curd) is obtained from pasteurised or boiled milk by souring, natural or otherwise by a harmless lactic acid or other bacterial culture, cane sugar may be added if preferred. Households use the previous day's dahi as the starter for their preparation. Today bacterial cultures in the form of ampoules are available in local markets for dahi preparation. If it is good quality, it does not have any wheying off and has a clean flavour. Confectioners (Halwais) concentrate the milk before inoculation and set the dahi usually in circular earthenware (modern packaging includes glass bottle and plastic or plastic coated cup). It has the same percentage of fat and SNF as the milk from which it is prepared. Average composition from whole milk is 5-8 per cent fat, 3.2-3.4 per cent protein, 4.6-5.2 per cent lactose, 0.70-0.72 per cent ash, 0.11-0.5 per cent lactic acid 85-88 per cent water. It is used for direct consumption either as such with salt or sugar or in the form of a popular beverage called lassi. Lassi is a whitish, viscous fluid with creamy mouth feel and rich aroma of diacetyl, it is mildly to highly acidic a property obtained on stirring Dahi with about 10-20 per cent water and sugar or salt, it is chilled when consumed in summer and directly consumed. Those who do not like drinking milk would consume Dahi readily; its biological value is 66 and digestibility 98 per cent. It contains antimicrobial and anti-carcinogenic factors, stimulates the immunological system and helps reduce blood serum cholesterol, with possible therapeutic value in stomach and intestinal disorders, due to its antibiotic content. The recommended storage temperature is around 5 to 10_C because it has short keeping quality at room temperature. On prolonged storage, it becomes highly acidic, accompanied by whey formation, making it unfit for human consumption.
Misthi doi is a sweetened, fermented milk product, traditionally prepared from cows' milk and consumed directly. It is nutritious, palatable and considered to be a delicacy in the eastern part of the country. It contains all the milk ingredients in a concentrated form together with sugar and caramel. Milk is mixed with sugar, concentrated by boiling, cooled and inoculated with culture (usually the previous day's dahi is used), and set in earthen pots. Good quality is characterised by firmly set curd with a fat layer at the top, slightly brownish appearance and a sweet taste with a mild and pleasant acidic flavour. Its average composition is 4.0 per cent fat, 13 per cent SNF, 18 per cent sugar, 0.1 per cent caramel and 64.9 per cent moisture. It is packed in earthen wares, poly-styrene cups (modern packaging), and the shelf-life at cold room temperature of 4_C is one week.

Technological innovations in dahi manufacture

Production of dahi is now being attempted on an industrial scale in a limited way. In one suggested process (Laxminarayana and Nabbudripad 1971) milk is standardised and pre-heated to 60_C and homogenised at 176 kg/cm². Final heat treatment is given at 80-90_C for 30-50 minutes, cooled to 22-25_C, inoculated with a lactic culture and added suitable cups. The cups are placed in an incubator at 22-25_C for 16 to 18 hours. dahi obtained in this way is stored at 5_C. Its keeping quality is about a week at refrigerated temperatures. Attempts have been made to extend its shelf-life by thermisation treatment (Baisya and Bose 1974). It has been claimed that bubbling of CO2 at one psi per minute before fermentation, yields a shelf-life of 15 to 30 days at ambient temperature (Tiwari and Singh 1966). Attempts have also been made for the production of dried dahi by spray drying (Baisya and Bose 1975). Such processes have been developed for the production of a dried dahi which could be set in a firm gel structure upon reconstitution. However, such a product lacked the rich aroma of a naturally fermented product.

Shrikhand is a semi-soft sweetish-sour whole milk product prepared from lactic fermented curd (dahi). The curd is partially stained through a cloth to remove the whey and thus produce a solid mass called chakka (containing an average 63.2 per cent moisture, 14.7 per cent fat and 0.8 per cent lactic acid). Chakka is mixed with the required amount of sugar, flavouring agents like saffron, and cardamom, to produce shrikhand. Consumed directly, it could be further desiccated over an open pan to make shrikhand wadi sweet. Also consumed directly, this contains an average of 6.5 per cent moisture, 7.4 per cent fat, 7.7 per cent protein, 15.9 per cent lactose, 0.8 per cent ash, 62.9 per cent sugar and one per cent lactic acid (as obtained from laboratory made samples from buffalo milk products). Shrikhand contains the total solids of dahi including protein and only a part of whey containing lactose, lactic acid and water soluble vitamins. Added flavours, aromatic spices, dry fruits and nuts, increase the caloric value of the product. It is packed in earthenware cups and in modern packaging like plastic or plastic coated cups. Recommended storage temperature is 5 to 10_C as it has short shelf-life at room temperature.

Technological innovations in Shrikhand manufacture

Shrikhand is also being manufactured on an industrial scale, in the process line developed by NDDB. In this process, skim milk curd made with a standard culture under controlled conditions from pasteurised skim milk, is centrifuged in a continuous quarg separator to produce chakka. This is then mixed with cream, ground sugar and flavours in a scraped surface heat exchanger for manufacture and pasteurisation of the product. It is then filled in a form fill and seal machine in a semi-aseptic environment before despatch for retail trade. Incorporation of modern technology and radical innovations in the traditional practices has not only made possible the manufacture of a safe, uniform, high quality product but has also enabled the organised sector to manufacture the product on an industrial scale and expand the market segment and improve its financial performance.
Coagulated (heat/acid) products

Milk is coagulated (separated out into solid and liquid portions) under varying conditions. This is undesirable when brought about by uncontrolled agencies. However, the same phenomenon has been exploited to concentrate the whole milk solids for edible purposes. Some products made on the basis of coagulation are described below.

Panir is an acid coagulated or rennet coagulated, small sized soft cheese. Traditionally, milk is boiled in a vat and coagulated with citric acid/malic acid at 70 to 85°C. A coagulum of casein-whey-protein complex with entrapped fat is formed, free whey is drained off from the vat and the coagulated mass is pressed in cloth lined hoops. The coagulum knits together into a compact spongy mass under pressure. After removal from the hoops, blocks are placed in chilled water for firming. Blocks are then cut into smaller pieces of suitable size for retail sale. Approximate composition is 55-70 per cent moisture, 22-26 per cent fat, 15-20 per cent protein, 2.0-2.5 per cent lactose and 2-2.2 per cent ash. The product may be loosely packed in polythene bags but could also be packed parchment paper. Normal shelf-life is one to two days for the traditionally made product or six days in refrigerated storage (5 to 10°C) though the freshness is lost after three days. Frozen panir can be stored for up to three months at 20°C and is as good as fresh.

Panir is used for direct consumption and also forms the base for a variety of culinary dishes and stuffing material for various vegetable dishes, snacks and sweetmeats. Though it can be produced from both buffalo and cow milk, panir from buffalo milk is preferred. It forms the base for a variety of culinary dishes, stuffing material for various vegetable dishes, snacks and sweetmeats. Different local varieties of Panir are:

Surati panir/Cheese is a rennet coagulated product and the best of the few indigenous varieties of panir or cheese. Cakes of surati cheese are carried over long distances by rail and road, floating in lactic whey in large sized earthen containers and sold directly to consumers.

Dacca cheese/panir is a small, medium-pressed cheese. Milk is first coagulated with rennet, then broken by hand and filled into small wicker baskets, whereas whey is pressed out by placing a board with a weight on the baskets. After 10 to 14 days, when the cheese pieces become sufficiently dry and develop a dried surface, the cheese is smoked, generally over cow dung smoke. The smoked cheese keeps well for one to two months. The combined tarry and furaldehyde flavour imparted by smoking is not liked by some people. During storage there is no breakdown of protein or fat, so the keeping quality is good.

Bandal cheese/panir is a small, soft type of Panir made from either cow’s milk or low fat cream. It is prepared in a more or less similar manner as surati panir, but is normally ‘smoked’ under crude indigenous conditions.

Chhana constitutes one of the two chief bases (the other being khoa) for the preparation of indigenous sweetmeats. It represents milk solids obtained by acid coagulation of boiled hot whole milk and subsequent drainage of whey. The acids commonly used are lactic or citric in both natural and chemical forms. Cow/mixed milk is brought to the boil by heating it directly in a traditional open shallow pan over an open fire, all the while stirring it with a ladle and later keeping it simmering hot in the pan. This hot milk is ladled out in batches of 0.5-1 kg into a separate coagulation vessel, either already containing, or to which is promptly added, the required quantity of the coagulant (normally cleansed sour chhana whey maintained in a large earthen vessel). The mixture of milk and whey is stirred with a ladle and when completely coagulated, poured over a piece of clean muslin cloth stretched over another vessel for receiving the whey. The process is repeated until all the milk is used up. The cloth containing the coagulated solids is tied up into a bundle without applying pressure and hung up not only to drain out whey completely but also to cool the contents (chhana pat) which are used in sweet preparations. The
average chemical composition from cows milk is 53.4 per cent moisture, 24.8 per cent fat, 17.4 per cent protein, 2.1 per cent lactose and 2.1 per cent ash (Ray and De 1953). It has a fairly high fat and protein content, contains some minerals, especially calcium and phosphorus. Its food and nutritive value is fairly high and it is a good source of fat soluble vitamins A and D. For its high protein and low sugar content, chhana is highly recommended for diabetic patients. Milk sweets from Chhana are:

**Rasogolla:** Balls made by kneading chhana with semolina and baking powder, cooked in sugar syrup.

**Sandesh:** Small cubes made by kneading chhana and cooking in sugar syrup over medium fire.

**Chhana-murki:** Small cubes of chhana, cooked in boiling sugar syrup till they attain sufficient firm body and close knit texture.

**Rosmalai:** Chhana balls cooked and served in thickened milk, sweetened with added aromatic spices and nuts.

**Clarified butter-fat products**

Products made in this method of preservation of milk form an integral part of the diet of the people of the Indian sub-continent.

**Makkhan** or butter normally obtained by churning whole milk dahi (curd) with crude indigenous devices, is essentially an input to the ghee (clarified butter) making process at household level though people also apply it directly on chhapatis (leavened bread). Buffalo milk yields whitish product, whereas cow milk product is yellowish. Dahi is mixed with cold water and churned in earthen vessels with a wooden beater, grains of Makkhan appearing on the top are scooped out and patted into a smooth compact mass having 18-20 per cent moisture, 78-81 per cent butter fat, 1.0-1.5 per cent SNF and not more than 0.2 per cent lactic acid. It contains vitamins A, D, E and K (fat soluble vitamins), small amount of essential fatty acids, arachidonic and linoleic acids. Parchment papers are used in packaging, for refrigeration and storage. Keeping quality is low under existing rural conditions but improved methods of production can enhance the keeping quality.

**Mattha** (butter milk) is the whitish, flavory, highly acidic fluid left over after churning Makkhan for the preparation of ghee in the unorganised, traditional, household sector. It is directly consumed, with or without any salt added.

**Ghee,** the butter-fat prepared chiefly from cow or buffalo milk, is the most common milk product in the Indian sub-continent. It is used as a cooking or frying medium, and is also consumed directly (with rice or chhapatis) apart from being used in confectionery and in traditional medicines. Traditionally, the household ferments whole milk into dahi and churns out makkhan (butter). Fresh or accumulated over days, makkhan is clarified at 105-145_C in a suitable open mud pot or metallic vessel, stirred continuously on a low fire to drive out all the moisture. The vessel is then removed from the fire and, on cooling, the residue settles down, and the clear fat is decanted into a suitable container. Ghee has somewhat longer keeping quality than makkhan and can be transported over long distances. Modern dairy plants manufacture ghee on a large scale. The development of an oxidised flavour or tallowiness in ghee is accelerated at higher storage temperatures. At household level, its storage temperature may vary from 5-38_C (usually recommended at 21_C) though refrigeration delays acid development and prolongs the keeping quality by rendering the product greasy and pasty. The average chemical composition of ghee from cow milk is 99-99.5 per cent fat, not more than 0.5 per cent moisture, 3.2-7.4 micro g/g unsaponiable matter in terms of carotene, 19-34 I.U./g Vitamin A and 26-48 micro g/g tocopherol. Free Fatty acid is limited to 2.8 per cent in terms of oleic acid (Agmark standard, that is, Indian Standards for
Ghee. In buffalo milk ghee, milk fat, moisture and free fatty acids are the same as in the case of cow milk ghee; unsaponifiable matter in terms of Vitamin A is 17 to 38 I.U./g and tocopherol is 18 to 31 micro g/g. Ghee contains Vitamins A, D, E and K, small amounts of essential fatty acids arachidonic and linoleic acids. Because it is susceptible to deterioration due to exposure to light, air and metals, tin-coated (non-toxic and non-tainting) containers are used for packaging. Food-grade plastic containers and polyethylene pouches are also used.

**Innovation in processing equipment for ghee manufacture**

In a continuous process developed by the National Dairy Research Institute (NDRI), the equipment consists of receiving-cum-heating vat, gravity separator (which becomes optional when making the product from cream), scraped surface heat exchangers coupled with vapour separators and positive displacement pumps to move the raw material through different units. A continuous ghee making plant has been recently developed by NDDB wherein the concentration of fat and breaking of fat in water emulsion is done mechanically with the help of centrifugal force in the clariffixator and concentrator and use of heat is limited to development of flavour and removal of traces of moisture. The plant developed by NDDB requires little energy and can be adopted for much larger volumes. The process also results in lower losses of SNF and better recovery of fat while reducing thermal pollution of environment.

Ghee residue refers to the charred (burnt) light to dark brown residue which is obtained on the cloth strainer after the ghee is filtered. The average composition of the residue is, depending on whether makkhan is derived from cow or buffalo milk, 32.4-33.4 per cent fat, 32.8-36 per cent protein, 12-15.4 per cent lactose, 5.2 per cent ash and 13.4-14.4 per cent water (Pralhad 1954). It is a rich source of milk fat, proteins and minerals. The residue obtained from the traditional makkhan-ghee process is appreciably richer in proteins and minerals. Its is consumed with rice or leavened bread and also in the preparation of ghee-toffees or *burfi* type sweets.

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Chapter nineteen
Dairy trade and marketing
B. Malcolm

Introduction

The discipline on production activities imposed by increasing competition in markets within and between countries will place under considerable economic pressure the most highly protected, highest cost, systems of dairy production and marketing in the world. High cost, protected dairy-farming is found in most countries in the tropics; set up and encouraged by governments to try to raise farm incomes and to service the growing demands of middle-income urban populations for milk products. However, smallholder dairy-farming can be efficient by using low cost labour and feed, and exploiting the natural protection from competition which arises from the liquid, bulky and perishable nature of liquid milk, and meeting local demand for fresh milk.

World dairy trade

Trade policy

Many countries have aimed to achieve self-sufficiency in the major dairy products, and maintain domestic prices well above international trade prices to promote dairy production and to raise dairy farmers' incomes. To achieve these aims it is necessary to restrict imports of the much cheaper dairy products which are available on international markets. The result is that countries without competitive advantages in dairy production have significant dairy industries and are even self-sufficient in dairy product. The policies implemented to achieve this domestic state of affairs, reducing domestic demand and encouraging domestic supply, ultimately have important implications for international trade and prices.
Whilst the General Agreement on Tariffs and Trade (GATT) came into force fifty years ago with the aim of facilitating less restrictive international trade, only in recent times have there been moves towards liberalising agricultural production and trade. This has come about after significant pressures for reform of agricultural policies from within the United States and the European Union, and follows the beginnings of economic growth over the past decade in Asia and South America which has added to world-wide demand for food products. The Uruguay Round of multi-lateral trade negotiations between the world's major agricultural trading nations, completed in December 1994, represented a tentative beginning along the long journey to liberalisation of international trade in food. Subsequently, agriculture has become subject to rules about improving market access, and reducing export subsidies and domestic price support. The main outcomes of the Uruguay Round are supposed to be implemented over the period 1995-99 for developed countries and 1995-2004 for developing countries.

The major elements of the Uruguay Round agreement are reductions, by 1999, in export subsidies to a value 36 per cent less than existed in 1986-90, and to a volume 21 per cent less than that which existed in 1986-90. The agreement also includes increased access to previously highly regulated and restricted dairy markets. Measures to increase access of exporters to importing country markets involved those importers that had restricted exports with non-tariff measures, converting these restrictions to tariff equivalents, as well as introducing quotas for products subject to tariffs to increase access to markets. Access by exporters to domestic markets under these arrangements is to be increased to five per cent of the domestic market by the year 2000. Protection is to stop increasing. New increased access quotas to the United States, the European Union and Japan were also part of the Uruguay Round. Countries retained the right to designate products as being trade-sensitive, which enables the imposition of temporary duties if a sudden increase in imports occurs. The overall effect is to establish maximum levels of tariff protection and prevent new barriers to trade being imposed. This is a significant step, representing a fundamental change in the direction of protection provided to agricultural industries, including dairying, in the major agricultural trading nations. These changes to the trading environment are being phased-in slowly, from high base levels of protection. The main impacts will not be realised until early next century.

In further developments, membership of the World Trade Organisation has expanded considerably compared with that of the GATT, and now includes a wide range of economies at varying levels of development. Further, in 1994 at the Asia Pacific Economic Co-operation (APEC) Summit in Bogor, member countries made a commitment to achieving the goal of trade and investment liberalisation by the year 2020, and by 2010 for industrialised economies. This was re-affirmed in the 1995 Osaka meeting, and the 1996 Manila meeting, which endorsed the Manila action plan for APEC that sets out trade and investment liberalisation and facilitation measures.

Generally, the methods of raising farmers incomes used nowadays are less distorting forms of assistance than used in previous times. Direct payments to farmers are used which are separated or `decoupled' from production decisions, having less distorting effects on production and consumption decisions. While average levels of agricultural assistance in industrial countries have not been reduced much, decoupled agricultural assistance measures used by North America and Western Europe reduces production for which there are no markets and reduces surpluses which depresses world prices for agricultural products. Increased trade liberalisation and decoupled assistance should slow the long-term downward trend in the real prices for agricultural products which are traded internationally, and moderate the policy-induced variability of agricultural product prices. Importantly, even though agriculture in the major OECD countries still remains highly protected and subsidised, there is greater recognition than ever before that the laws of supply and demand for agricultural production and consumption are powerful, and that attempts to repeal or resist them are costly, wasteful and ultimately, futile.

The use of artificially high milk prices at farm level has consequences for world trade and export prices. For example, the European Union (EU) produces one quarter of world milk supply. Seventy-five per cent
of the milk produced in the EU is sold at prices far above world prices. The remaining 25 per cent of milk produced in the EU has no domestic uses because it is too costly, so the EU disposes of it by subsidising its sale on domestic and world markets, at an annual cost of around $5.5 billion. The United States runs a similar system of high-priced domestic milk surpluses, subsidised onto world markets. As well, most middle and low-income countries protect their dairy-farming activities from world price competition with high trade barriers. The result is that the accessible world market for exports of dairy products is a small fraction of total world demand for dairy products. Only seven per cent of world dairy production enters world trade. As the export dairy market is small compared to domestic markets, small changes in demand and supply caused by good or bad seasons in one or other of the major producing countries, causes significant changes in supply available for trade, and thus significant changes in prices in the export markets. Consequently, the export market price for dairy products fluctuates more than domestic prices in most countries.

There are some important changes taking place in dairy production in the EU and the United States. The overall effect is to expose dairy producers in those countries to lower prices through reduced supports. In the United States the support price for dairy has been abolished from the year 2000. In Europe there is a continuation of a fundamental change in agricultural policies that started in 1992. A further change is that there are 10 Eastern European countries that are already part of a special association arrangement with the EU, and that are expected by 2005 to have domestic surpluses of milk of 2.6 million tons. The cost to the EU of subsidising these levels of production is daunting, even to the EU, and the European Parliament has conceded that further change to dairy production and marketing arrangements will be needed. The United States has World Trade Organisation commitments to reduce subsidies, and although the 1996 United States Farm Bill confirmed that export enhancement incentives will still be used to promote exports of dairy products, pressure is on the United States to reduce the production of subsidised exports of dairy produce.

**World dairy production, trade and prices**

How much milk is produced in the world, where, and by whom, is shown in Table 19.1. Overall, world milk production since 1990 has been stable, with declining milk production in some Eastern European countries, and increases in the United States, Australia, New Zealand, parts of South America, and India. In tropical countries since 1990, milk production as a share of world milk production has increased significantly in India and Brazil and increased to a lesser extent in Mexico, Colombia and Tanzania.

Trade in milk production in international markets each year is only a very small proportion of total milk production. Trade in the major products, bulk butter, cheese, milk powders, casein and condensed milk, accounts for around 34 million tons of milk equivalent or seven per cent of total world milk output. As well as being affected by restrictions on direct access, the patterns of international trade in dairy products are also affected by the increases in milk supply caused by policies that raise domestic prices. In dairying, only a few countries are significant exporters. New Zealand accounts for only two per cent of world milk output but is the second largest seller of manufactured milk products on the world market, exporting 80 per cent of its production and accounting for around one quarter of export sales on a milk equivalent basis. Australia produces less than two per cent of world milk, exports 45 per cent of total production and accounts for around ten per cent of export sales. The major exporter is the EU which provides 47 per cent of all export sales. During the 1990s the United States increased exports following the 1990 Farm Bill's export enhancement provisions and supplies eight per cent of world exports. The EU, New Zealand, Australia and the United States account for 90 per cent of total world exports with the remaining 10 per cent of exports coming from other exporters such as Canada, non-EU countries of Western and Eastern Europe, Argentina and Uruguay. In recent times, Poland and the Czech Republic are increasing exports of milk powders, and the Baltic States are also playing an increasingly active role in world trade. Dairy products from these newer exporters go mainly to the Middle East, Central and South America, North
Africa and South East Asia.

Asia accounts for over half of all skim milk powder (SMP) and whey powder imports, one third of whole milk powder (WMP) imports, and around 20 per cent of butter oil, cheese and liquid milk imports, including condensed milk. Seventy-five per cent of the liquid milk imported into Asia is ultra heat treated (UHT). The Americas account for nearly 30 per cent of all imports of cheese, SMP, WMP and whey powder and milk. Africa imports cheese (23 per cent of export supply), butter oil (18 per cent), SMP (16 per cent), WMP (18 per cent) and liquid milk (15 per cent). The Middle East imports 15 per cent of butter oil exports, 13 per cent of world cheese exports, 11 per cent of WMP exports and 11 per cent of liquid milk exports. Whole milk powders are widely sold in areas of tropical countries where supplies of liquid milk and refrigeration are limited.

The EU has a dominant role in determining traded prices in international markets where milk products are sold under free market conditions. This is distinct from the portion of export sales which occur under bilateral quota arrangements, where prices reflect domestic arrangements and are above free trade prices. Generally, export prices in non-quota markets are equal to the domestically supported price for products in the EU minus the EU export refund or subsidy. Further international market price changes are significantly influenced by exchange rate changes; stockholdings of surpluses by the

**Table 19.1. World dairy production (adapted from data in Australian Dairy Corporation Annual Compendium 1996).**

<table>
<thead>
<tr>
<th>European Union</th>
<th>1995 milk production (000t)</th>
<th>Change in milk production from 1991 to 1995</th>
<th>of 1995 world milk production (FAO estimates)</th>
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</thead>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>8381</td>
<td>Stable</td>
<td>1.79</td>
</tr>
<tr>
<td>India</td>
<td>32000</td>
<td>Increasing</td>
<td>6.84</td>
</tr>
<tr>
<td>China</td>
<td>5764</td>
<td>Slowly increasing</td>
<td>1.23</td>
</tr>
<tr>
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<tr>
<td>Bangladesh</td>
<td>782</td>
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<tr>
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<tr>
<td>Iran</td>
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<tr>
<td>Israel</td>
<td>1136</td>
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<td>0.24</td>
</tr>
<tr>
<td>Africa</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Production (thousand t)</td>
<td>Trend</td>
<td>Price (US$/kg)</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>South Africa</td>
<td>2495</td>
<td>Slowly increasing</td>
<td>0.53</td>
</tr>
<tr>
<td>Egypt</td>
<td>1000</td>
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<tr>
<td>Kenya</td>
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<td>Morocco</td>
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<td>Sudan</td>
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</tr>
<tr>
<td>Tanzania</td>
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<td>Oceania</td>
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</tr>
<tr>
<td>Australia</td>
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<td>Increasing</td>
<td>1.92</td>
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<tr>
<td>New Zealand</td>
<td>9850</td>
<td>Increasing</td>
<td>2.11</td>
</tr>
<tr>
<td>Total from table</td>
<td>437566.00</td>
<td>Stable</td>
<td>93.51</td>
</tr>
<tr>
<td>World Total (FAO)</td>
<td>467919</td>
<td>Stable (466,000-467,000 since 1992)</td>
<td>466,000-467,000 since 1992</td>
</tr>
</tbody>
</table>

N.B. Not included: some Caribbean countries and some African countries.

governments of the EU and the United States; regulations about subsidised domestic usages of milk products in the EU and the United States; seasonality of supplies from producers in Australia and New Zealand; food aid supplies; United States export incentive sales to `win' new commercial markets; and the timing of major import tenders. The main force affecting world trading conditions for dairy product is the exchange rate of the ECU, which in turn has traditionally been very strongly influenced by the value of the Deutschmark.

Nearly all world milk production takes place in countries which protect dairy farmers from competition and heavily subsidise their production to pay higher than world export prices for milk equivalents. Only New Zealand and Australia have low protection of dairy production that results in domestic surpluses which are exported. The prices dairy farmers receive for producing milk around the world vary considerably (see Table 19.2). Australian farmers are able to produce milk and sell it to dairy manufactures for around 22 cents (US) per litre while New Zealand and Argentina milk prices are 10 to 30 per cent less than the Australian prices, depending on exchange rates. The farm gate price of milk in the United States is around 40 cents a litre. In the EU, farm gate price is nearly double the lowest world prices per litre. In the most efficient of the EU countries, Ireland, milk costs 49 cents a litre to produce. The least efficient EU dairy farmers in are paid 58 cents a litre in Denmark and Swiss farmers are paid about 105 cents per litre. Japanese farmers are paid about 140 cents (US) per litre.

**Table 19.2. Approximate 1996 dairy product wholesale prices expressed in $US/ kg (Australian Dairy Corporation 1996).**

<table>
<thead>
<tr>
<th></th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Butter</td>
</tr>
<tr>
<td>Japan</td>
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</tr>
<tr>
<td>UK</td>
<td>4.03</td>
</tr>
<tr>
<td>United States</td>
<td>2.22</td>
</tr>
<tr>
<td>Australia</td>
<td>2.06</td>
</tr>
</tbody>
</table>
Milk in tropical countries

Milk production

Tropical regions in parts of Asia, the Middle East, South/Central America and Africa produce one third of the measured cows milk produced annually throughout the world (Table 19.1). Small numbers of specialist dairy farms operate in all tropical countries. Commercial dairy production is found in tropical regions between 300 meters and 1500 meters altitude. While significant tropical dairy industries can be found in Kenya, Zimbabwe, India and the Caribbean, for many sound reasons, dairy farming has been slow to establish in the tropics.

Milk production in the tropics has been limited by the extreme climates, by low quality tropical feeds that are generally high in fibre and low in digestibility and have a short season of growth. Also limiting milk production are the diseases and parasites associated with hot and wet conditions. Milk yields per cow have been low and seasonal. As well, land tenure, economic incentives and marketing systems, transport and distribution systems, and support services such as credit, veterinary services, equipment and technical advice, have often been inadequate for highly productive, profitable dairy production of the type common in more developed countries. Therefore, most of the milk produced in tropical areas has come from the farming operations of millions of smallholders and semi-nomadic owners of cows, buffalo, sheep, goats and camels, and generally has been a sideline to other more profitable cropping or pastoral activities.

Cows produce two-thirds of all milk produced in tropical countries. Dairy production in most tropical countries has had a large subsistence family component, with smallholders mostly producing cows milk for family food, and selling any seasonal surpluses, and importantly, with each cow rearing a calf. The typical subsistence operations would have two to four milking cows, or buffalo that are kept for cropping activities. Once the cows are milked, tropical environmental conditions make it difficult to keep milk without refrigeration, so milk is usually delivered soon after milking. It is then boiled before use or converted to other products such as ghee, cheese, fermented, and concentrated products. Where conditions are more conducive to temperate animals in the medium altitudes and humid coastal regions, pure-bred cows (particularly Friesians) are preferred. Large commercial dairy farms are found in tropical Australia and in Central and South America, in the Pacific and Caribbean islands and the high land areas of East Africa and in Israel, and West Asian countries.

Milk consumption

Measured milk consumption varies considerably between, and within, countries in the tropics. Milk is a traditional, widely used product in India, and in much of Africa, the Americas and the West Indies. While wealthy consumers in poor countries regard milk as a basic food product, poor people in poor countries regard milk as a supplement to the traditional diet. For the urban poor in poor tropical countries, milk and milk products are usually too expensive for them to buy in significant amounts. At the same time rural poor use milk and dairy products from their own livestock as a major source of food. In India, even low-income city groups buy considerable amounts of milk and milk products. Some pastoral tribes in Africa rely almost exclusively on milk as their only source of food protein for periods of the year.

Measured milk consumption is around 35 litres per person per year in Asia, 20 litres per person per year in Africa, 92 litres per person per year in Latin America, and 300-400 litres per person in Western Europe. Within countries, consumption varies widely between and within social groups. While growth of milk output has exceeded the growth rate of the populations in industrialised economies since 1960, milk
production in the low and middle income tropics has been increasing at around three per cent a year while, on average, demand has been increasing at a slightly faster rate. Demand for milk and dairy products has increased in tropical areas where people's incomes have been growing. The increasing demand for milk and dairy products in most low and middle income countries has mostly been met by imports. For example, the large majority of milk requirements of Malaysia and the Philippines are imported or made locally from imported ingredients.

There is a wide range of liquid milks and preserved milk sold in tropical countries and a wide range of packaging materials and methods used. Also, there are a number of options regarding the combination of dairy ingredients with ingredients of vegetable origin (called imitation milk or filled milk). In the Philippines, Thailand and Malaysia over half the milk consumed is in this form. Consumption of liquid milks or milk preserves in tropical countries is widespread, either in concentrated or powdered forms, but not fermented products and cheeses. In the Middle East, and to a lesser extent Latin America, fermented products and cheeses are consumed. On the Indian sub-continent, in North Africa, and the high plains of eastern South Africa, some milk sold is used for cured products, but consumption is small. In South-East Asia, little fermented milk product is used.

**Dairy industry development**

In most tropical countries since the 1950s, development of dairy production and marketing systems have been promoted by national governments and international agencies. The World Bank, FAO and UNICEF have all played major roles in fostering dairy development throughout the tropics. Governments of developing countries have long held that dairy development is integral to broader rural development, and dairy policy forms part of national economic policy. This approach sometimes overlooks the technical suitability, or unsuitability, of the production and marketing systems. The superficially appealing notion of agricultural, and other, self-sufficiency has usually been the underlying motivation for dairy development efforts in tropical countries. Increases in domestic milk production and decreases in milk powder imports are complementary aims, and frequently expressed goals in dairy development plans.

The initial model for dairy development was that which prevailed in the wealthy industrialised parts of the world which had the following characteristics: highly technical and intensive; highly regulated; protected from competition; based on artificially high prices; heavily subsidised; paying farmers to produce milk for which there were limited markets. This model has since proved very costly and inappropriate for the wealthy countries, even though it worked at least in a technical sense. In the low-income, harsh-climate tropics, this model had neither technical nor economic sense going for it. Nowadays in the wealthy industrialised countries, more enlightened governments are trying to reduce the extent to which their taxpayers and consumers pay dairy farmers large sums of money to produce milk which is unwanted.

Many early dairy development attempts in the tropics failed because they were not appropriate in either technical or economic terms. The hard lesson to be learned in economic growth and development theory is that each country is a unique case. The situation in each country is a unique product of unique history, unique resources and unique combinations of resources - there can be few general prescriptions for economic growth and development.

Numerous milk industry development schemes have been set up by governments in the tropics, though rarely with success. Too often the appropriate balance between public and private activity has not been struck. The inevitable high costs, low output, and other failures in production and marketing arising from the early *ad hoc* and uncoordinated attempts to transplant modern developed country dairy production and marketing systems lead, in the 1980's, to the approach captured in the catch phrase `integrated dairy development programs`. It had been found that in the early stages, dairy development based on the complex, sophisticated, imported technology, high yielding animals, concentrate feeds and high consumer
prices and taxpayer subsidies of the wealthy countries did not work. More progress was made emphasising locally available resources, with the aim of gradually improving productivity. An adequate supply of trained personal was needed, and the incentives via prices paid to producers for indigenous milk production had to be appropriate. Often, the prices of imported dairy products, including non-commercial imports under bilateral or multilateral aid programs, were low enough to be a disincentive to local production. Later efforts in dairy development were directed toward integrating milk production, processing and marketing, to try to ensure resources were not wasted whilst pursuing appropriate returns to milk producers and improving quantities and quality of milk for urban and rural consumers.

**Dairy industry in tropical Asia**

**India**

The milk produced in India is distinctly seasonal. It comes from cows and buffalo in equal proportion, with a small contribution from goats. Cows produce, on average, 446 litres of milk annually and buffalo produce 861 litres of milk annually; buffalo milk ranges from six to nine per cent fat content. Eighty per cent of all local milk is consumed in liquid form.

The growth in milk production reflects India's unique history, industry and policy structure set up under Operation Flood which the Indian Government, the World Bank and the European Community food aid funded. It was designed to achieve milk self-sufficiency early next century. Annual production of raw milk from all sources in India is 57 million tons having increased from 20 million tons in 1970, and is expected to reach 78 million tons by 2000. India is the fourth largest milk-producing region in the world, after the European Community, United States and the states of the CIS.

Operation Flood is a system of rural milk producer co-operatives that purchase, process and market milk, provide technical services and infrastructure. The early funding of Operation Flood One was done through commercial resale of dairy product received as aid under the World Food Program. The product came from the European Community and the revenue from sales of aid product was used to develop infrastructure for local co-operatives. Operation Flood Two set up the institutional framework comprising a three tiered co-operative structure of societies, unions and federations. Operation Flood is now in its third stage and involves eight million dairy farming families. There are 200 milk processing plants in the co-operative, government and private sectors which receive 11 million litres of milk per day. Operation Flood dairies market three-quarters of this total. Under the Operation Flood scheme, daily supplies of milk are collected from over 60,000 village milk procurement centres to meet consumer demand for drinking milk. This accounts for 5.5 million tons or ten per cent of total milk produced. The remaining 90 per cent of milk is utilised on-farm, sold to small operators in nearby towns, or used to produce ghee or other products. The demands of consumers in the four major cities of India: Bombay, New Delhi, Calcutta and Madras, and the regional variations in milk supply, led to the establishment of a National Milk Supply Grid system via train and road tankers. Rural producers are linked with urban consumers through the National Milk Supply Grid by moving milk from surplus to deficit regions. Barriers to trade are substantial and there is a domestic dairy policy of increased self-sufficiency. India's imports have been declining as a proportion of total production. Imports are subject to 60 per cent tariffs, plus state sales taxes and general excise duties.

**Malaysia**

In 1971 the Malaysian government introduced its New Economic Policy which strongly supported the development of the local dairy industry. The government established and operated a number of large dairy enterprises, and assisted the development of private farms. It established a system of centralised milk
collection centres. Sixty per cent of milk produced is collected and sold through official milk collection centres, with the remainder being sold direct from farms or through local vendors. About 65 per cent of milk from the milk collection centres is used for domestic dairy manufacturers. Government support has been by direct investment in farms, promotion of consumption through schools, and restrictions on entry of imported milk and milk products. In recent years, direct government support has diminished. There has been a move toward more market-oriented production and processing. Malaysia's domestic liquid milk production makes up half of milk consumption, and the rest is from UHT milk recombined from imported skim milk powder and butter oil milk. Processors rely heavily on imported products. Thus tariffs are low on dairy products compared with other foods, and dairy import licenses are readily obtained.

**Indonesia**

Indonesia has an average 30 per cent tariff on imports of dairy products which substitute for products manufactured locally. A tendency to refer to average tariffs or tariffs on commodity products rather than special or branded products can be misleading. For example in Indonesia, cheese has a 50 per cent tariff which is to be reduced to 40 per cent in the year 2004, and bulk whole milk powder for infants has a tariff of 238 per cent (up from 30 per cent in 1995), reducing to 210 per cent in the year 2004. There is also a VAT imposed on all dairy product imports equal to 10 per cent of the landed duty paid price. There are also local content rules about milk processing, as well as investment controls on some milk processing activities. Milk substitutes such as liquid milk, powders, condensed milks and milk concentrates, may only be imported by firms who hold certificates (BUSEPS) showing they have utilised a set volume of locally produced milk. The ratio is one unit of local milk to two units of imported milks. The effects of the BUSEP arrangement are that local milk supplies are guaranteed a market outlet through the capping of import competition. Imports of fresh and UHT milk are prohibited because of the need to purchase matching BUSEPS; and returns to all processors tend to be equalised by the transfer of BUSEP payments from importers of lower cost inputs to users of higher cost local milk.

**Thailand**

Before 1960 Thailand had no domestic dairy industry, with the exception of the activities of some minority immigrant groups. The small demand for milk products was met by imports. In 1978 locally produced milk was expensive compared with recombined milk from imported product and the Thai government initiated a program to increase self-sufficiency in milk. In 1982 the government started restricting imports of fresh milk and milk powders, and established the Dairy Farm Promotion Organisation to act as a major collection agency for raw local milk and to produce finished milk products for retail sales. Since 1983 local milk production has expanded rapidly. In 1982 Thailand had 13,700 cows producing 27,240 tons of milk. By 1991 the number of cows and amount of milk had increased six-fold. There were 12,000 dairy farms and the average herd size was 6.3 cows, each yielding about 10 litres per day. Milk consumption in Thailand is low by world standards, at 12 litres per person on average. Around 50 to 60 per cent of all milk products consumed in Thailand are consumed in Bangkok, which has 15 per cent of the population. In rural Thailand dairy product consumption averages 2.5 litres per head. Over half of the fresh milk consumed in Thailand is produced locally.

The Thai dairy industry has grown under protection from competition provided by the trade barriers, such as quantitative and tariff restrictions on imported products. Customs duties range from 25 to 60 per cent on dairy products, plus other business and municipal taxes. There is also a local content scheme applying to imports of milk and milk substitutes (Butter oil, SMP, WMP). These regulations require importers to purchase two kilograms of locally produced raw milk for every kilogram of imported milk equivalent. Consequently milk imports are minimal. Consumption has risen sharply over the past decade, partly due to government efforts to promote milk use through subsidised schools programs, as well as rising
to government efforts to promote milk use through subsidised schools programs, as well as rising incomes. The local content rules have eased recently as local supplies have not been able to keep up with demand.

Dairy marketing in the tropics

Milk production and consumption levels, the range of products consumed, and consumer habits and attitudes in relation to milk products, vary considerably from country to country and even within a country. However, the nature of the product involved is the main determinant of product marketing systems that will develop. To minimise deterioration of quality in the tropics, milk has to be moved to the customer within two to three hours of milking, or milk products have to be made which will keep without refrigeration, or preservatives added to the fresh milk, or it has to be cooled as soon as possible on the farm or at a collection centre. Well-organised milk schemes collect milk from widely-scattered suppliers, chill it in bulk, and transport it to processors with minimal delay.

Most commonly, milk processing in tropical countries is characterised by inadequate technological and economic conditions. Specialised dairy farms in the tropics can be found in districts close to urban milk markets where each farm may sell 50 to 200 litres of milk, directly to city customers, or to a city milk plant. These farms produce milk from pure-bred or crossbred temperate dairy cows. Furthermore, small farmers are increasingly trying to produce milk regularly for sale directly to customers in their village or nearby cities, or to private milk vendors, or to a milk plant in the local region. However, despite attempts to develop local commercial dairy-farming, much of the milk sold in urban areas in the tropics is manufactured wholly or partly from imported ingredients.

Technical aspects of the processes involved in transforming a product on a farm into something a consumer wants, when they want it, and where they want it, are critical determinants of the marketing system which operates for any agricultural product. In the case of milk, the nature of the product - liquid, bulky, perishable, produced by many small producers - determines the detail of the milk marketing systems which develop. In highly regulated sectors of an economy such as the milk sector of most economies, which have price controls, state-owned distribution channels and government brands, regulations about the use of local raw materials or vegetable origin and so on, the application of marketing concepts developed for competitive production and marketing situations can be constrained. Even so, basic marketing rules apply to all markets, whether developed or less developed.

The dual economy characteristic of many countries in the tropics is also an important determinant of which systems and strategies of milk marketing will succeed. Generally, there are enormous disparities of incomes between a small segment of very affluent people, a larger but still relatively small middle-class segment, with rather low income, and a huge mass of people representing a minor share of total disposable income, say less than 20 per cent. This situation changes only very slowly. Combined with the high cost of locally produced milk in the tropics, the result is that milk and milk products are not items the whole population can afford to buy, and milk consumption per head will grow in line with growth and distribution of income. The income disparities in tropical countries also means the key to any milk marketing strategy in developing markets is segmentation of the market according to income of the potential buyers.

Milk-marketing activities are, to a great extent, determined by technical considerations such as the nature of the product and the relative locations of the producers and consumers, and the distinct income-segmented markets. The relative economic power of buyers and sellers is also crucial in determining the structures of the marketing system. The nature of milk production as an agricultural activity, and of milk as an agricultural product, is the main reason for the dominant role played by producer-owned cooperatives in milk marketing. The key principles underlying the establishment and operation of marketing
Co-operatives are to do with bargaining power and economies of scale in activities. Co-operative marketing evolves because on one side of the trade of milk are many small producers with a product which is perishable and costly to transport. On the other side of the market in the local area is a single relatively large buyer or a small number of relatively large buyers who assemble, process, distribute and retail milk. These imbalances of market power have led to producer co-operatives being the mainstay of dairy marketing throughout the industrialised world. Milk producers have long recognised the economic sense of being/owning the local monopolist. Co-operatives have also evolved to supply services and inputs to farmers, particularly credit for producing a commodity that is seasonal, and markedly so in the tropics. Co-operatives can have the effect of setting up misleading price signals, with producers taking some of their benefits in the form of input subsidies, dividends and rebates. Further, the principle of equal shares makes it difficult to mobilise capital if most members are small farmers. There is a perennial problem of competing aims of the producers as producers, and as owners of the co-operative. Producers want high returns for their produce while co-operatives need to restrict product prices paid so as to build up capital through retained earnings for replacement and expansion of capital.

**Prospects**

The two key factors underlying considerations of prospects for dairying are income elasticity of demand in low and middle-income countries, and the relative rates of technological progress in dairy-farming and milk processing in exporting and importing countries.

People in low-income countries have higher income elasticity of demand for all foodstuffs than people in wealthier countries. Rapid economic growth and rising populations means people are earning higher disposable income, which is often accompanied by changes in diets, which in turn widens markets to a greater range of processed foods. Thus commodity exporters such as dairy traders in countries with highly developed agricultural and dairy-farming systems, facing stagnant or slowly growing demand for milk and milk products, will be looking increasingly to low to middle-income countries experiencing significant economic growth. For example, the significant increase in Australian dairy production during the 1990's was built around a large increase in exports to countries in Asia, including Tropical Asia. Recent economic growth in Tropical Asia has moderated from the high levels of the first half of 1990s. Rapid annual growth rates in Thailand, Malaysia and Indonesia were accompanied by large current account deficits, strong inflationary pressures, and major collapses of currency values, and annual economic growth has slowed markedly. Economic growth in Latin America has been less than one per cent per annum in recent times but is expected to be around four per cent per annum in the near future. Similar results are expected in the Middle East and Eastern Europe, whilst significant economic growth remains a forlorn hope in most of Africa in the short to medium term.

If technological improvements in milk production and processing occur at a greater rate in countries which currently export milk products than occur in tropical countries which are trying to meet growing local demand, then relatively cheap world exportable milk surpluses will continue to grow, and place increasing pressure on milk importing countries for access to their markets. A key issue is the extent to which countries will continue to pursue self-sufficiency policies. While traditionally tropical countries have protected domestic agricultural production, growing populations mean newly-industrialised countries face significant constraints in bringing new land and technology into agricultural production. Eventually, as growth proceeds, many of the developing tropical countries will find that a more liberal world trading environment in the future, exporting manufactured goods, and services, and importing food, will be a less costly, more profitable approach than striving for food self-sufficiency.

To achieve the potentially large gains to income and welfare which are made possible by freer trading arrangements, liberalisation of trading arrangements has to occur across all sectors of all economies.
Increased exports by some countries implies increased imports by those same countries. A simultaneous requirement is increasing exports by importing countries, for them to be able to afford to buy the increased exports of the exporting countries. Liberalisation of trade in goods and services, to ensure that developing countries are able to benefit from comparative advantages in sectors such as textiles and clothing, will mean these countries will generate income necessary to import their food requirements. Regional trading arrangements, such as APEC, also have a major impact on the trade environment. There is a danger that failure to deal appropriately with agriculture in the context of regional arrangements and regional trading blocks will either entrench or severely limit the degree of liberalisation necessary. This is a possibility in respect of NAFTA and also with a number of EU agreements with East European countries, which have the potential to restrain the opportunity that developing countries have to exploit trade and to generate income to overcome their poverty and food insecurity problems.

**Conclusion**

The argument presented in this chapter is that the nature of milk as a commodity shapes the production and marketing systems which evolve. In the tropics, the dairy sector which services low-income people in local rural markets, comprises small-scale fresh milk producers. In this situation efficiency derives from using labour and feed supplies which have low opportunity costs, or involves joint production, and thus in local regions there is some degree of natural protection against competition because of the perishability of milk and cost of transporting liquid milk. There is another dairy sector which services the urban middle-income population and produces high-cost local milk which is used in conjunction with restricted import material to produce reconstituted liquid milk and manufactured products. Tendencies towards liberalisation of trade in agricultural commodities will have different effects on these two dairy sectors.

If genuine and significant trade liberalisation happens eventually, the effects will be manifest in two ways, and will be different for the two dairy sectors. First, improvements in dairy technology in exporting countries and reduced barriers to trade will mean consumers in tropical countries whose wealth is growing will have greater access to less expensive dairy products from other countries. This will affect the local dairy sector servicing the urban middle-income populations. The extent of any impacts will depend on the relative rates of change in demand for milk products and supply of imported milk products, and on the extent of technological efficiency gains achievable in medium-sized commercial dairy production and in dairy processing in tropical countries vis-à-vis exporting countries.

Second, a corollary of freer trade in agricultural commodities is freer trade in all goods and services. For countries to be able to import they have to be able to export. If a general liberalisation of trade occurred it would mean greater applicability of the principle of comparative advantage in resource use within and between countries. This would mean lower exchange rates for the previously highly-protected economies, and greater competition between resources involved in non-agricultural export production with resources currently devoted to agriculture. The most highly-protected activities would decline and resources would move into activities which would contribute to earning export income or to import-replacing activities which could be done without protection. In tropical countries the dairy sector serving the middle income urban populations does not usually come under either of the categories `export income earner' or `efficient import replacing'.

However, the rate of change towards freer trade throughout the world is glacial, with much backsliding, as countries continue to protect their inefficient business activities. This fact, along with the `naturally protected' nature of liquid milk as a commodity means that in those amenable areas of the tropics where dairy-farming `works' to a reasonable degree, the small-scale, fresh milk producing industry which serves local, low-income, rural populations, uses low opportunity cost resources, and exploits joint production possibilities, dairy-farming will continue to be rewarding.
Suggested reading


Australian Dairy Corporation. Dairy Market Briefings (various).


Chapter twenty
Smallholder dairy co-operatives
N.V. Belavadi and M.K. Niyogi

Smallholder dairying and development
The Indian experience
Kaira District Co-operative Milk Producers' Union (Amul)
Anand pattern co-operatives
National Dairy Development Board (NDDB)
Operation Flood Programme
Dairy co-operative development under Operation Flood
Dairy co-operatives in other tropical countries
Bangladesh
Sri Lanka
Social impact
Conclusion
Suggested reading

Smallholder dairying and development

Small holding farmers of most of the tropics are caught in a situation of low return per unit of productive asset, inaccessibility to resources and market, ignorance and other economic and social compulsions. However, braving all such adversities smallholder dairy farmers in some tropical countries have taken a bold step towards creating their own infrastructure of marketing and production support services through their own dairy co-operatives. Today India, with its nation-wide dairy co-operative network of small holding dairy farmers, has emerged as a major dairying nation in the world and many other countries have shown similar developments.

An essential feature of the developing countries is that the innermost secrets of a rural society are revealed in terms of production relations. Land and livestock provides persons with a sense of power, security, wealth, opportunity, and social standing. However, the individual relations with land are more complex, ownership is generally subject to formal records and operational rights, and product distribution often lacks the necessary transparency. Ownership of livestock and its production sharing is comparatively straightforward and informal in nature. As a result, the land holding pattern is highly skewed across all the developing countries whereas there is an emerging trend of more equitable distribution of livestock, particularly large ruminants.

High population growth rates and breaking up of the traditional family structure into smaller units (married couple and young children) has changed the traditional subsistence farming system. A large section of smallholder farmers has emerged in developing countries looking for opportunities to maximise their production from land-livestock-labour based production system and barter or monetise to meet their...
family needs. Rural labour market limitations and linkages with agricultural production, which again suffers from lack of transparency in the wage system, has caused migration to urban areas, either permanently or seasonally. Nonetheless, the majority of rural people have remained attached to their land and livestock and struggle to optimise the returns from their limited productive assets.

Rapid urbanisation in some developing countries has created domestic demand for high value food items creating market opportunity for indigenous production, particularly milk and milk products. Unfortunately, in most of the countries, existing production and rural marketing systems can not respond readily to the rising demand and local Governments in general have resorted to an easy option of importing milk and milk products from developed countries either as food-aid or commercially. Thus, a market force that could have been used for increasing the productivity of the rural livestock sector has actually helped the livestock economy of developed countries at the cost of local producers.

Smallholder dairy farmers in rural areas of developing countries are also confronted with many problems inherent to their undeveloped economy. They are isolated from the market due to poor transport and communication networks. Under these circumstances, the rural market in most of the tropics must factor in costs of transport, communication and risk. Farmers having a small quantity of individual farm produce cannot trade in a distant urban market nor do they have adequate bargaining capacity to avoid exploitation should a middleman so act. The low production potential of their dairy animals, lack of knowledge of advanced production technology, non-availability of adequate production inputs and services have added to the misery of smallholder dairy farmers. The service sector, which is mostly managed and controlled by the government is often inadequate and sometimes insensitive to farmer needs.

An answer to these issues lies in the collective effort of small holding dairy farmers in creating their own institutions serving their collective economic interest and the Government's willingness to promote such efforts with adequate policy and legislative support. For smallholder dairy farmers, an owned and managed co-operative can provide an effective link with urban consumers. Unlike trade in respect to imported commodities, this linkage distributes a share of the earnings from the urban consumer back to rural areas. Rural institutions thus formed can handle business transactions on behalf of individual farmers and provide a common forum for transaction of knowledge and information along with the services. A federated body of such institutions, depending upon its volume of business, can wield considerable bargaining capacity and competitiveness at the market place by value addition and superior consumer services.

Cash earning by the milk producers, often on a daily basis, through sale of milk changes the consumption pattern of goods and services, and can influence other rural economic transactions. While development of major infrastructure in rural areas would continue to depend on Government schemes, peoples’ initiative in managing their own business enterprise democratically encourages development of micro-infrastructure in rural areas through greater participation and often willing financial contribution.

With recent rises in international prices dairy commodities from developed countries are no longer a viable alternative for many developing countries. This situation provides an unprecedented opportunity to develop the indigenous dairy industry, by organising smallholder dairy farmers into co-operative organisations.

The Indian experience

Agriculture plays an important role in the Indian economy. About 29 per cent of the national income is derived from agriculture and allied activities providing livelihood to about 64 per cent of the population. Even now farmers depend on bullock power for tilling, irrigation and cartage because cultivated land is
mostly in small fragmented holdings of less than two hectares. Most farmers keep one or two cows to produce male offspring to be reared as bullocks. Milk production from such cows has traditionally been a by-product of bullock production. However, during the last two decades, crossbred cows have found favour particularly in areas endowed with better resources and infrastructural facilities. On the other hand, buffaloes are kept basically for milk production and contribute to approximately 55 per cent of the country's milk production.

In most parts of the country milk production by each rural household is small and as the surplus available after household consumption is only marginal, farmers depend on the traditional milk vendors or traders to sell the remaining milk available. As farmers are at the mercy of traders/vendors for sale of milk and as the traders exploited them in the past, farmers have become apathetic to better management practices for increasing milk production. Consequently, farmers did not readily adopt scientific practices of better feeding and management leading to low milk production. Farmers in many parts of the country, faced with such a vicious cycle of low milk production due to lack of assured market or an undependable traditional market for milk, would convert the surplus milk available into Ghee (clarified butter) which has a much longer shelf life at room temperature and enjoys a sizeable traditional market. Although Ghee production did serve the rural milk producers in terms of reduced dependency on traditional traders, it was nevertheless unremunerative, especially for cows milk which has a relatively low fat content.

Kaira District Co-operative Milk Producers' Union (Amul)

The Kheda (Kaira) district which is located in the state of Gujarat had a traditional relationship between milk producers and traders. This became more noticeable with the Bombay Milk Scheme in 1945 when milk had to be transported from the small town called Anand in Kaira District of Gujarat to Bombay, a distance of more than 400 kms. This could only be done if milk was pasteurised. After preliminary trials, the Government entered into an arrangement with a privately owned dairy, to supply milk on a regular basis from Anand to Bombay. The arrangements were highly satisfactory for all concerned except the farmers who were not guaranteed a price for their milk. They had to sell milk at the price fixed by traders. Farmer discontent grew. Thus, under the Bombay Milk Scheme promoted by the then Colonial government, the farmers of Kaira district were no better off than before. A deputation of these farmers approached Sardar Vallabhbhai Patel, a great Indian leader, who advised farmers to market their milk through a co-operative of their own, with its own processing plant. His advice was that the farmers should seek permission to set up such a co-operative and if this was rejected they should refuse to sell milk to the middlemen. Sardar, however, pointed out that while taking such a stand there would be losses to the farmers as they would not be able to sell milk for some time. Nevertheless if they were prepared to bear the losses, he was ready to lead them. The farmers deputation accepted Sardar's proposal willingly. Farmers decided to form a dairy co-operative society in every village of Kaira district and to form a union of the village dairy co-operatives called the Kaira District Co-operative Milk Producers Union Ltd. It was decided that the union would buy milk from the village dairy co-operatives and send processed milk to the Bombay Milk Scheme. However, the Government turned down the terms of the co-operative to which farmers responded with a milk strike which lasted for fifteen days. The Milk Commissioner of Bombay relented and the union was formally registered on December 14, 1946.

The Kaira Union began its operations with just a handful of farmers from two village dairy co-operatives supplying about 250 litres of milk every day. An assured market proved a great incentive to the milk producers leading to exposure of the concept. The Union soon realised the need for professional management and assistance, and was able to have a team of dedicated managers to steer its growth. Keeping pace with the increasing milk collection it created necessary processing capacities, initiated a set of milk production enhancement measures including services such as animal health care, breeding facilities, fodder seeds supply, and balanced cattle feed aimed at increasing milk production. The Kaira Union, under the brand AMUL, manufactured milk powder and baby food from buffalo milk for the first
The success achieved by combining the farmers' power with the management by professionals in an integrated co-operative structure assured incentive to increase milk production, and exposed farmers to the process of development by placing the required tools in their own hands. The Union now handles on an average about 736,000 litres of milk per day, has nearly 553,000 milk producer members belonging to 970 village dairy co-operatives in the district. It owns modern processing facilities with a capacity to handle up to 1.5 million litres of liquid milk per day. It possesses large scale manufacturing facilities for products such as butter, milk powder and baby food and cheese. The Union provides round the clock veterinary services and balanced dairy cow rations. It also provides artificial insemination services through village dairy co-operatives by establishing its own network of bull station, frozen semen production and delivery system. A flow chart showing the relationship between producers, dairy co-operatives and consumers, is presented in Figure 20.1.
Anand Pattern Co-operatives

In just one decade of existence the AMUL had shown that dairy development through co-operatives is a viable option. It attracted interest from planners, policy makers and leaders. Soon farmers from districts neighbouring Kaira sought help of AMUL for organising dairy co-operatives. With AMUL’s assistance a few more milk unions in Gujarat came into being. The pattern of dairying established with Anand as the base in Kaira district and subsequently in other districts of Gujarat, became popularly known as `Anand Pattern'.
The basic unit of Anand Pattern is the village dairy co-operative - a voluntary association of milk producers in a village who wish to market their milk collectively. Any milk producer can become a member of the co-operative society on the condition that they own a cow or buffalo and are willing to supply any surplus milk to the co-operative. At the annual general meeting of members they elect representatives (normally nine persons) to form a management committee responsible for governance in accordance with the bylaws of the co-operative. The managing committee frames the plans and policies that govern day-to-day affairs of the society. Village milk collection, testing for quality, sale of cattle feed, payment to producers every day, accounting and all such tasks are handled by paid employees from the same village. The paid staff are appointed by the management committee and their remuneration is based on the earnings of the co-operative. The co-operative also provides services such as artificial insemination (AI) and veterinary first-aid (VFA). Therefore, these primary societies also generate local employment in the rural community. Each producer's milk is tested and paid for on the basis of quality. The co-operative collects milk every day in the morning as well as evening at specified times fixed by the milk union. Usually, the morning milk is paid for in the evening and the evening milk is paid for next morning and in certain cases the payment of milk price is linked to the weekly market days. Most societies accept as little as half a litre of milk from individual milk producers. If one visits a village dairy co-operative it is possible to see as many as 100 to 150 milk producers queuing every morning and evening to sell their milk to the co-operative.

Village dairy co-operatives are affiliated to the district milk union which generally owns and operates milk processing plants and other facilities required for assisting the milk producers enhance production. Thus the union is a co-operative jointly owned by the village dairy co-operatives of the district and performs functions which the village co-operatives themselves cannot individually perform. From the chairpersons of the village co-operatives, the Board of Directors of the union is elected. It has the responsibility for ensuring appropriate policies and management of functions and activities such as collection and transportation of milk from the village dairy co-operatives, arranging regular and timely payment for the co-operatives, processing and marketing of milk and milk products and providing technical input services to farmers. That Board is also responsible for long-range and strategic planning; for framing operational policies; representing the union on legislative and regulatory bodies; communicating with members, and the overall control of affairs. The union is a professionally managed co-operative enterprise. It has a Managing Director reporting to the Board of the union and a team of professionals and staff. Normally the Union provides services such as emergency veterinary care for the animals owned by the farmers, supply of balanced cattle feed and breeding services aimed at improving the genetic quality of the dairy animals, supply of improved varieties of fodder seeds to promote cultivation of green fodder by farmers and extension services. The union also undertakes training and education programs for producer members, management committee members and, staff of the Village Dairy Co-operative Societies.

**National Dairy Development Board (NDDB)**

The success achieved by the Kaira Milk Union (Amul) prompted the Government of India to set up a body called the, National Dairy Development Board (NDDB) which aimed to replicate the socio economic changes brought about by the Kaira milk union and the village dairy co-operatives. With this mandate, the NDDB tried to convince each of the State Governments to make some funds available for dairy development based on the Anand Pattern, albeit with limited success.

**Operation Flood Programme**

At the time when NDDB was attempting to promote Anand Pattern co-operatives as the best approach to developing India’s dairying, it was noticed that there were mounting surpluses of dairy commodities in
Europe and NDDB saw in it an opportunity that could be used for extending dairying on Anand Pattern in India. In 1969, the NDDB formulated a programme called `Operation Flood' which proposed utilisation of the `food aid' available in the form of dairy commodities from donor agencies such as the World Food Programme to generate funds for replication of Anand Pattern dairying in the country. Responding to this proposal the WFP committed commodity assistance involving 126,000 MT skim milk powder and 42,000 MT of butter oil for the first phase of the Operation Flood Programme which was to link the four major metropolitan cities with 18 potential milk sheds in the country. The program envisaged monetisation of gifted commodities through sales to the already existing dairies in Delhi, Bombay, Calcutta and Madras which remained under-utilised due to paucity of liquid milk. Phase-I of Operation Flood was launched in 1970 with a total outlay of Rs.1, 160 million generated from the commodities given by WFP. In converting the donated commodities into liquid milk and selling it through existing metro-dairies, the NDDB ensured that donated commodities would only be sold at prices at par with locally produced milk so that the local market would not be depressed, and that funds generated would be invested in setting up milk sheds in the hinterland areas of metropolitan cities. The program was based on some simple assumptions:

- dairying in India is supplementary to agriculture and provides supplementary income to a vast majority of farmers,
- milk production in the country is characterised by a very wide dispersion of rural production over millions of small production units situated far away from the market place,
- the market and the price are the primary incentives to increase production and farmer income.

In less than a decade of implementation the Operation Flood Programme had clearly demonstrated the replicability of Anand Pattern Dairy Co-operatives. This led to initiating implementation of a second phase with finance from the World Bank and European Union from 1979 for expansion selected Districts in most of the States. The second phase of implementation was followed by phase three commencing in 1987 which consolidated achievements by improving the productivity and efficiency of the co-operative dairy sector and its institutional base.

The Operation Flood Programme actions included:

- promoting and assisting milk producers in establishment of village dairy co-operatives and co-operative unions
- creation of additional milk chilling, processing, distribution and marketing facilities to be owned and operated by the Dairy Co-operative Unions
- creation of sufficient conversion capacities with the Co-operative Dairies for balancing the lean and flush supplies
- establishment of a network of storage and long distance milk transport facilities to enable operation of a national milk grid
- equipping the dairy co-operatives with facilities for providing a set of milk production enhancement inputs to farmer members to improve productivity of their dairy animals
- development and provision of support services such as information systems, training and manpower services for the co-operatives
- establishment and management of centralised support services such as animal disease diagnostic centres, vaccine and biological production and delivery systems, and a national frozen semen system to enhance the productivity of dairy animals
- promotion of indigenous development of dairy processing and conservation methods and establishment of dairy machinery and equipment manufacturing facilities in the country in order to cater to the need of a growing dairy industry
- establishment facilities and undertaking research and development activities.
Dairy co-operative development under Operation Flood

As a result of various actions under the three phases of the program, the country witnessed a phenomenal increase in milk production. Milk production which was almost stagnant around 23 million MT per annum during the 1970s rose to a level of around 69 million MT per annum (1996-97) with India emerging as the second largest milk producer in the world. Despite the growing population the per capita availability of milk which was declining, has significantly increased, reaching a level of more than 200 g per person per day. There were about 74,500 village Dairy Co-operatives federated to 170 district milk unions across the country. In most of the States, the unions have State Dairy Federations. Around 10 million farmers have become members of the village dairy co-operatives. Last year (1997-98) these co-operatives collected on an average 12.26 million litres of milk every day (Table 20.1).

The program has been an outstanding success encouraging farmers to take up dairying as the most important subsidiary occupation. It has offered a regular and reliable source of income for farmers with more than 62 per cent of milk procurement in the Operation Flood areas comes from the marginal farmers and landless households.

Table 20.1. Progress of dairy co-operatives in India (1996-97).

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Unit</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-operative milk producers' unions</td>
<td>Nos.</td>
<td>170</td>
</tr>
<tr>
<td>Village co-operative milk producers' societies</td>
<td>Nos.</td>
<td>74314</td>
</tr>
<tr>
<td>Farmer members</td>
<td>Nos. `000</td>
<td>9595</td>
</tr>
<tr>
<td>Rural milk procurement</td>
<td>Million kgs</td>
<td>4473</td>
</tr>
<tr>
<td>Liquid milk sale to urban consumer</td>
<td>Million litres</td>
<td>3836</td>
</tr>
<tr>
<td>Powder production</td>
<td>MT</td>
<td>92851</td>
</tr>
<tr>
<td>Village societies having AI facilities</td>
<td>Nos.</td>
<td>17791</td>
</tr>
</tbody>
</table>

Commercial import of dairy products was completely stopped in mid 1970s as the indigenous production of milk powder and butter started increasing. The indigenous production of milk powder which was insignificant during the early 1970s is now about 160,000 MT per annum.

Delhi, Bombay, Calcutta and Madras together account for almost 40 per cent of the total milk marketed by the co-operatives/Operation Flood dairies. Altogether, Operation Flood dairies in metropolitan areas, market around 3.2 million litters of liquid milk per day. Other cities and towns account for the sale of around 4.8 million litres of liquid milk by the co-operatives.

Dairy co-operatives in other tropical countries

Similar collective efforts of organising dairy industry though farmers' owned and managed dairy co-operatives in other tropical countries, have met with varying results depending upon the prevailing socio-political environment and opportunity for peoples' initiative. Although, many countries in the tropics have adopted a democratic governance system in recent years, the democratic values, which forms the basis of the co-operative initiative, are yet to take root in local social and economic life, creating an atmosphere of establishing large democratic institutions. Indian experience has clearly demonstrated that a genuine political will and government commitment towards fostering democratic institution at the grass root level,
are pivotal factors for establishment and growth of an effective farmer owned and managed dairy co-operative network. Therefore, while collective efforts of smallholder dairy farmers in many countries has shown some positive result, they are yet to establish themselves as a major economic force.

**Bangladesh**

For decades, Bangladesh had a large domestic market for milk and milk products which was largely met through importation of subsidised milk and milk products from developed countries. During 1989-90, Bangladesh imported milk and milk products worth 400 million Taka to meet a short fall of 40 percent of domestic demand. Due to huge importation at a subsidised rate, the price of milk and milk products in major urban markets remained low and the milk produced in semi-urban areas found its way to major urban demand centres through a network of middlemen.

There are around 24.5 million cattle in Bangladesh of which around 10 million are breeding cows. They provide milk, meat, draught power, transport and hide, an important export item. Dairying is practised in Bangladesh as a part of local crop-livestock farming systems, typically one to two animals and half an acre of land unit. The cows are mostly maintained as bull mothers and little surplus milk (0.5 to 1.5 litres per day) is available for household consumption.

A social worker, took initiative in forming the Eastern Milk Products Ltd. a private company in 1952 and started marketing dairy products under the trade name of Milk Vita. In 1965, this dairy was transferred to the Eastern Milk Producers' Co-operative Union Ltd., the first milk producers' co-operative formed in the country. Around 100 village level milk producers' co-operative societies were formed around Lahirimohanpur where the plant was located in Sirajganj district. During the same period, another dairy plant was established at Dhaka and run by the National Co-operative Marketing Society, marketing liquid milk in the city. Eventually, both the dairies declined.

In 1973, the Government initiated a dairy co-operative of smallholder dairy farmers following the Indian experience and launched a dairy development program - 'Co-operative Dairy Complex' with financial assistance from Denmark. While taking over the dairying infrastructure created at Lahirimohanpur and Dhaka, the new organisation maintained the earlier name of Eastern Milk Producers' Co-operative Union for a few years until it was renamed as Bangladesh Milk Producers Co-operative Union Ltd. in 1977. The brand name, Milk Vita remained unchanged.

Today there are around 40,000 smallholder dairy farmers who have joined as members of around 345 primary dairy co-operatives covering about 925 villages in 15 districts of Tangail, Manikgonj, Tekerhat, Baghabarighat, Sree Nagar and Rangpur areas, supplying over 50,000 litres of milk per day. Farmer members pool their surplus production at the primary dairy co-operative societies which arrange regular cash payment on the basis of fat content and the Bangladesh Milk Producers' Co-operative Union Ltd. (BMPCUL) ensures regular collection, processing and marketing of milk and milk products. The dairy co-operatives also provide necessary support services to farmer members for animal breeding, feeding, health and training in animal management. In addition, a major part of the surplus earned by the central dairy co-operative through marketing milk and milk products is paid to the members.

After the Chernobyl disaster in 1987 import of milk and milk products from the European countries was temporarily suspended by the Bangladesh Government. This, along with the trend of increasing the price of milk and milk products in the global market, has led to a fresh initiative towards self-sufficiency in milk production. Since 1986, milk production in Bangladesh has increased by 26.35 thousand metric tons and imports have decreased by 16.8 thousand metric tons annually. Of the total national consumption of 18 million tons of liquid milk a year, 15 million tons is produced indigenously.
It is interesting to note that while organised marketing efforts through dairy co-operatives and cross breeding of indigenous cattle has helped the crop-livestock smallholder farm sector to flourish, commercial dairy farms set up peri-urban areas are being shut down, as they find it difficult to meet the high input costs.

**Sri Lanka**

In Sri Lanka, the agricultural sector contributes around 18.4 per cent of the national GDP and the livestock sub-sector contributes nearly six per cent of sectoral GDP. Almost three quarters of total two million hectares of agricultural land in Sri Lanka is distributed among nearly two million smallholder farmers. The rest comes under large estates raising plantation crops. Dairying is a major component of the livestock sub-sector in Sri Lanka and is essentially dependent on a large number of crop/plantation-livestock farmers. In plantation areas, workers are increasingly depending upon dairying to augment their income by keeping crossbred cows. In other districts, where settlements were established about three decades ago with three acres of land per family, the younger generation shows marked preference for smallholder dairy farming to maximise viability of fragmentation of land holdings.

According to the Department of Census and Statistics, Sri Lanka had 1.7 million cattle and 0.8 million buffalo in 1995. The estimated milk production in 1995 was 333.3 million litres, 76 per cent of which was cow milk and remaining 24 per cent was from buffalo. Over the last two and half decades cow milk has increased at an annual rate of two per cent and buffalo milk at 2.3 per cent. Indigenous production of milk meets about 30 per cent of the country's demand. In 1996, milk and milk products worth Rs. 6045 million were imported from developed countries.

The initial efforts of the government for dairy development in Sri Lanka have been in the form of establishment of government farms, importing cattle and buffalo, introduction of artificial insemination, and expansion of health care services. Although the institutional arrangement for milk procurement and marketing was initiated by the government by establishing the National Milk Board in absence of any organised procurement system, the informal sector took the initiative of linking the dairy farmers and government owned processing plants, and over time, the `milk collectors' emerged as a major `middleman' service to dairy farmers. This situation forced the Sri Lankan Government, in 1972, to restrict the National Milk Board to purchase milk through co-operatives only. Unfortunately, there was hardly any dairy co-operative in Sri Lanka at that time and in certain areas some multi-purpose co-operative unions entered into the milk procurement business. At the same time, large-holders persuaded the government to allow a selected number of farmers with a large volume of milk to supply directly to the National Milk Board plants.

The first major attempt at smallholder dairy development was initiated in 1976 with assistance from the World Bank to organise dairy farmers into producers co-operatives. Although around 150 dairy co-operatives were established under the project, most funds were utilised for building of infrastructure, and a separate government extension wing was created to assist the operations of these co-operatives.

Over a period of time, the Sri Lankan Government has created several agencies for dairy development activities such as the Department of Animal Production and Health, the National Livestock Development Board, Milk Industries of Lanka, and Integrated Rural Development Project Mahaweli Agency of Sri Lanka. The Government of Sri Lanka has over the past three decades invested over Rs 1.5 billion for increasing indigenous milk production, and some 32 bilateral and international dairy development projects have been implemented without significant impact. The Government policy of involving multiple agencies in the milk business has resulted in haphazard growth of various dairying institutions without significant participation of milk producers in managing them.
In Sri Lanka, there are around 265 co-operatives with a total membership of over 58,000 smallholder dairy farmers spread all over the country. Most dairy co-operatives operate in a large area covering a number of villages. These co-operatives which are basically engaged in milk procurement and delivery to major milk processors suffer from political interference, involvement of government officials in management and limitations imposed by the statute. There are around 110 chilling plants with capacities ranging from 1500 litres to 15,000 litres spread over the country. Almost all the processing capacities, including powder manufacturing, are owned by government or private multinational companies like Nestlé. Farmers close to chilling centres supply milk directly. In many places groups have been formed and registered as co-operative societies or associations which collect milk from members and supply nearby processing facilities. MILCO has also started its own collection centres and procures milk directly from the milk producers or from dairy co-operatives or associations. Similarly, Nestlé collects milk from farmers or from dairy co-operatives and associations or through private agents. There are also five Dairy Producers' Co-operative Unions which collect milk from both registered co-operative societies and a number of unregistered farmer groups, and supply either MILCO or private operators. Similarly, many multipurpose co-operative societies procure milk from a large area and supply milk to chilling centres.

Contrary to popular belief, creation of multiple milk collecting agencies in rural areas has created unhealthy competition in the rural market and constrained domestic production. The milk producers are paid a fraction of consumer rupee, often as low as 40 per cent, and the competition for a limited quantity of milk has led to compromise in quality. In this environment, dairy co-operatives are unable to function according to co-operative principles and producers do not have a role in deciding issues related to processing, marketing or pricing of milk and milk products.

Recently, the government formed a joint venture company, Kiriya Milk Industries of Lanka Pvt. Ltd. with the National Dairy Development Board, India, to organise dairy farmers, introduce quality parameters and organisation discipline. Initial efforts have already resulted in significant improvements in quality of milk and an average increase of around 30 per cent in farmer incomes.

**Kenya**

In contrast to the production structure of earlier decades, when most of the milk was provided by the large producers, currently over 80 per cent of the estimated 1500 million litres milk produced annually in Kenya comes from the smallholders. The Rift Valley Province and Central Province are the major dairying areas in Kenya with plantation-livestock and crop-livestock farming systems.

The Government of Kenya played an active role to promote smallholder dairy farming through Dairy Co-operative Societies. While the Ministry of Co-operative Development was responsible for registering, supervising the co-operative elections and accounts, and authorising capital expenditure and policies, the Kenya Co-operative Creameries provided centralised support through a guaranteed market outlet and national uniform pricing. Until recently (May 1992) the Kenya Co-operative Creameries (KCC) had a monopoly in urban milk marketing licensed by the Kenya Dairy Board, and dairy co-operative societies and other private dairies did not have many options but to sell to KCC. In 1992, the monopoly for urban milk sales held by the KCC was removed. As a part of on-going economic reform, the Government of Kenya reduced the level of support for veterinary and breeding services allowing a greater role for the private and co-operative sectors.

Smallholder dairying and dairy co-operative societies have consequently changed substantially. The monopoly on milk marketing created problems such as delayed payment to the producers, often of several months. In order to avoid such constraints, some smallholder dairy farmers formed less formal self-help groups for the purpose of marketing of milk. Many dairy co-operative societies and self-groups are now directly marketing raw milk through their own marketing networks in urban, semi-urban areas.
Directly marketing raw milk through their own marketing networks in urban, semi-urban areas, particularly to institutional consumers and private traders. This has also increased milk sales and prices paid to producers. There are around 300 Dairy Co-operative Societies of which some 200 are presently operating. Some large multipurpose co-operative societies are involved in the milk business among other businesses. After an initial set back after 1992, the dairy co-operatives have regained a substantial market share in 1996.

A recent study conducted by the Kenya Agricultural Research Institute and International Livestock Research Institute, shows the quantitative and qualitative changes that have taken place in dairy co-operative sectors in central province which accounts for 71 per cent of annual milk turnover in co-operative sectors. Milk sales, as well as the level and coverage of services in animal breeding, health care, feed and credit facilities, provided by the dairy co-operative societies, have also improved demonstrably.

**Social impact**

The dairy co-operatives in India have recognised that farmers' returns can be increased by lowering costs, that is, increasing their efficiency, just as well as by raising producer prices. They have also recognised that the ability to lower costs has enhanced the dairy co-operatives' competitive position. Co-operatives have been fairly successful in providing the needed services to village level institutions and farmers. They have trained a large number of villagers to a high degree of competence and capitalised rural India's low cost labour and increased productivity.

Dairy co-operatives have focused on a single productive activity, not aiming at removing economic and social inequalities existing in rural areas for centuries. Nonetheless, as a ripple effect, a farmer-controlled co-operative dairy industry is not only capable of pooling very small deliveries, one or two litres, of milk from individual smallholder dairy farmers, it also provided a dependable alternative of livelihood by offering an assured market and attractive price by eliminating the middlemen. In India, dairying shifted, in many cases, from a sideline activity to a serious economic enterprise and, in some cases, even became the main source of farm income. Dairying is particularly valued because of the reliability and regularity of payments, and is relied upon to pay recurring household expenditures, leaving crop income to finance investments and major social events.

Farmer owned village institutions have provided access for their members to poverty-oriented programs such as credit and subsidies to purchase dairy animals, biogas construction and improved water supply. For those landless people who own or have been able to purchase a dairy animal, it has been a boon. Increased production of milk has also improved nutritional status of the rural people through increased retention of milk for household consumption.

Women in most Indian villages have a socially constricted role of homemaker with little control over household income. They play virtually no visible role in political and social arena. Operation Flood, in collaboration with NGOs, has established more than 6000 women's dairy co-operative societies which have empowered women to meet collectively and explicitly make their own decisions. Leadership talents have emerged, and self-confidence has grown. Because dairying is their primary and usually only commercial activity, women when empowered prove more adept at the utilisation of improved husbandry methods than men. When women receive milk income, it enables them to make most household expenditure without having to ask the male members for money and even allows them to save small amounts for emergencies.

There is high-income elasticity of demand for education in Indian villages. In poorer villages, milk income means the difference between going to primary school or high school. In wealthier villages, where school attendance is almost universal, some of the earnings of the co-operative are set aside to help the
local education institution. More girls attend school in the villages with a dairy co-operative society.

One of the major lessons learnt by the dairy co-operatives in India is that poverty is best combated by providing productive employment. Milk marketing through dairy co-operatives can profoundly effect nutrition, incomes, job creation, education, and empowerment of women, particularly among smallholder dairy farmers.

## Conclusion

The collective strength of the smallholder milk producers of these countries does indicate the prospect for further impressive increases in the milk production. However, the success of Operation Flood and other dairy development programs seem to be perceived as a threat to the further growth of dairying in developed countries. This is evidenced by some unreasonable restrictions or non-tariff barriers being imposed by these nations which are detrimental to smallholders in developing countries. This is one challenge confronting the collective efforts of the smallholder dairy farmers throughout the tropics.

### Suggested reading


Chapter twenty-one
Successful smallholder dairy projects
S.R. Na Phuket

Introduction

Dairy development in many developing countries involves smallholders. Most smallholder dairy development projects and programs have been developed and implemented by the governments and mainly with technical and financial supports from international or bilateral organisations. Experience in Asia on the success of these projects and programmes so far has been mixed. Many of these projects were classified as unsuccessful or partially successful under donor's respective criteria. The common problems of these multi- and bi-lateral assisted projects and programs are that they have focused on larger project size with a high proportion of foreign exchange components. Therefore these projects involved investment in large importation of animals, and heavy infrastructures and equipment such as dairy processing plants and large feedmills, and, in some cases, vaccine production plants and sophisticated diagnostic laboratories. These facilities, in most cases, are not appropriate for the requirement, maintenance capability, and working tradition of the countries concerned. Operation of these facilities and even management of these projects usually requires the assistance of expatriate consultants. Therefore, these projects have become costly, uneconomical, non-implementable, and non-responsive to the need of smallholders who are targeted beneficiaries, and thus are unsuccessful and unsustainable. However, in all of these unsuccessful projects, there are project components which could be classified as successful ones. These successful components usually involve smallholder farmers such as farmer training; extension, breeding and health services; provision of input supplies, milk collection facilities, credit etc. These successful components generally require less investment cost, and thus have contributed less to the overall project classification. The prerequisites for the successful and sustainable smallholder dairy development could be best drawn from experience and lessons learned from past projects.

Experience in smallholder dairy development projects and programmes

Features
Smallholder dairy development projects and programmes have been developed mostly by governments and supported by bi- and multinational agencies. These public investment projects commonly aim at meeting countries' socio-economic objectives, that is, creating employment, combating poverty, increasing incomes of mainly smallholder farmers and rural landless labourers, improving human nutrition, and fostering economic development.

The main objectives of these projects and programs have included:

1. enhancing dairy productivity through improved disease control, management, nutrition and genetic potential of animals
2. increasing the supply and availability of dairy products through improved milk collection, processing, and marketing facilities and systems; and
3. maximising the utilisation of natural resources through better utilisation of agricultural wastes, agro-industry by-products, and waste lands.

These objectives were to be achieved through:

1. the establishment and/or upgrading of veterinary laboratories and clinics, animal quarantine and vaccine production facilities, feedmills and feed laboratories, artificial breeding facilities, and milk collection, processing and marketing facilities, as well as extension and training facilities and institutions
2. the importation and distribution of improved animals and genetic materials
3. the provision of extension and veterinary services, training and credit to farmers
4. provision of training and fellowships for government staff
5. provision of consultant services; and
6. stimulating private sector investment in the dairy subsector.

**Project performance and impacts**

Project performance and impacts of livestock projects could be learned from the Asian Development Bank (ADB) experience. With their long involvement in the sector in Asia since 1969, such development agencies have accumulated considerable experience in the design and implementation of livestock projects and programs, most of which includes dairy development. Several problems and difficulties were encountered in the implementation of livestock development projects, and the results have not been as expected in most cases. Out of ten post-evaluated projects (Table 21.1), eight were deemed not to have met appraisal targets of economic viability, while only two were considered to be partly successful. Nevertheless, these projects have made contributions to developing countries in a number of ways. The more important contributions are:

- shift in orientation of public livestock agencies from primarily regulatory and animal health services to providing support to dairy and livestock production and marketing systems as well as smallholder livestock agribusiness
- increased infrastructure facilities to better serve livestock raisers, particularly the centres for animal health, extension and AI services in remote areas, which would otherwise not have been built
- the upgrading of expertise in the delivery of veterinary, extension, marketing and input supply services, and in farmer organisational development;
the establishment of sustainable development processes such as improved integration of livestock into agricultural production systems

- sustainable improvements in livestock productivity through increased supply and delivery of improved genetic material at the farm level, improved feeding methods and fodder production, and livestock disease control

- increased rural employment including on-farm employment through the raising of livestock and the handling and processing of livestock and livestock products;

- increased participation of the private sector, including NGOs, in livestock transportation, marketing and input supply (including credit)

- increased distribution of economic benefits to smallholder farmers a significant proportion of whom could be classified as rural poor; and

- improved nutrition of smallholder households through the increased consumption of milk, eggs and other livestock products.

Table 21.1. Livestock projects evaluated by the Asian Development Bank.

<table>
<thead>
<tr>
<th>Borrower</th>
<th>Project</th>
<th>Amount $ million</th>
<th>Project period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>Livestock Service Development</td>
<td>12.40</td>
<td>1978-85</td>
</tr>
<tr>
<td>Indonesia</td>
<td>South Kalimantan</td>
<td>20.50</td>
<td>1979-87</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Sumatra Livestock</td>
<td>16.70</td>
<td>1981-89</td>
</tr>
<tr>
<td>Korea</td>
<td>Livestock Feedmills</td>
<td>13.00</td>
<td>1979-86</td>
</tr>
<tr>
<td>Nepal</td>
<td>Livestock Development</td>
<td>12.28</td>
<td>1979-87</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Baluchistan Livestock Development</td>
<td>7.50</td>
<td>1979-97</td>
</tr>
<tr>
<td>Philippines</td>
<td>Smallholder</td>
<td>8.00</td>
<td>1981-88</td>
</tr>
<tr>
<td>Solomon Is.</td>
<td>Beef Cattle Development</td>
<td>3.57</td>
<td>1976-84</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Livestock Development</td>
<td>15.20</td>
<td>1982-92</td>
</tr>
<tr>
<td>Western Samoa</td>
<td>Beef Cattle Pilot Farm</td>
<td>0.33</td>
<td>1971-77</td>
</tr>
</tbody>
</table>

These results have been achieved, in different degrees, in most of the post-evaluated projects. However, because of the necessary long duration of livestock projects and the absence or inadequacy of benefit monitoring and evaluation systems for them, the above contributions could not be quantified or comprehended at the time of the evaluation. As a result, performance of these projects appears to be more discouraging than it really is.

Factors affecting the success of dairy development projects

Despite the above-mentioned weakness in evaluating the projects, the post-evaluated livestock development projects failed to achieve appraised objectives for a variety reasons. For most, poor performance stemmed from over-ambition at the design stage leading to over-investment and the targeting of large numbers of small farmers over a widespread area without linking them to a supervisory and marketing apex and credit system. Also, the government's capability in and commitment to the provision of adequate counterpart funds and staff and its adherence to the agreed procurement procedures were not adequately examined, and output objectives of the projects were not adequately focused. The above design shortcomings were exacerbated by implementation difficulties, often by inadequate commitment...
Successful smallholder dairy projects

Project design

While most projects claimed to target smallholder farmers, the project design generally failed to take account of the realities of dairy as part of the smallholder farming system, particularly the role of the farm family in farm management. Typically, the development paradigms, as comprehended by public sector agencies, have tended to lead to the imposition of predetermined institutional requirements on design which severely limited design options and overrode the priority of farmers and other producers in determining the requirements for improving livestock productivity.

Predetermined institutional requirements in the past made it almost imperative that most project management would be executed by public sector agencies with all the associated people management constraints. This is in spite smallholder dairy development being of necessity, primarily people-oriented and requiring a high level of commitment of individual participants in project implementation for achieving project objectives. Moreover, most governments have established institutional arrangements that treat livestock and dairy production as if it were an independent enterprise despite the fact that dairy animals plays an integral role in complex smallholder farming systems, linking production to the use of the farmland and by-products, wastelands, and nearby forests and plantations, as well as providing fertiliser, fuel and food. Government livestock agencies, notably those for extension and adaptive research, are usually separated from those for crops.

Moreover, methodologies adopted in project design in critical areas such as the provision of extension, animal health, input supply and marketing services have typically been based on academic assumptions or long-established organisational procedures, with little or no participation by major recipients of services and in several cases, without considering available resources, particularly animals. Demand-led development as a concept is still relatively new, and is likely to take some time before becoming universally accepted and institutionalised. The adequacy of supervision and technical capability, willingness of the executing agencies, and availability of market outlets were often overlooked, thereby causing the project design to introduce less comprehensive technological packages targeting very large numbers of small farmers over widespread areas. This shifted project focus from activities determined primarily by producer needs based on mainly local investment to livestock imports and the introduction of high cost, sophisticated technologies based on imported plants, equipment and expertise.

Furthermore, with regard to credit provision to farmers, conditions imposed on the processes by which resources could be transferred typically through development finance institutions impeded effective delivery. Procedures and accountability provisions and interest rate levels tend to dominate as the major issues of credit program design, while the prerequisites for sustainable, low cost and appropriately directed credit delivery systems with major farmer-involvement, were seldom considered, or received low priority at best. As with most public sector agencies, mechanisms for participatory planning involving potential credit recipients are either non-existent or poorly developed, virtually precluding any major opportunity for establishing truly effective livestock credit programmes.

These narrowly focused project designs typically failed to address major issues of project financing, particularly in respect of the government's provision of staff and local counterpart funding. While all project agreements included government assurances of availability of local funds and staff, little or no
attention on project design was given to this aspect, which could contribute to project implementation difficulties. Overriding attention of the involved public sector agencies given to achieving physical input targets rather than achieving project objectives appeared to have downplayed the importance of deriving benefits from the project investments by the implementers, thus reducing project impact. Proper project monitoring focusing on the achievement of benefits would have yielded better results and facilitated project evaluation.

**Project implementation**

Deficiencies in project staffing can often be attributed to poor budgetary planning procedures by executing agencies and low government commitment. Relaxing of staffing requirements and other critical conditionalities forming part of project design, which resulted from inadequate commitment by governments encouraging faster project implementation, has been the major cause of implementation difficulties and project failures. On the other hand, non-flexibility in changing project design and scope in response to changing circumstances also contributes to project failures. Poor acceptance of procurement procedures of funders by financing and regulatory agencies of recipient governments has been responsible for major delays in project implementation, and thus failure to achieve project targets. Other factors which also caused delays include:

1. lack of familiarity of the executing agency with funder procurement and disbursement procedures and the establishment of credit instruments
2. a large variety of different items being required for a single component such as, a vaccine production facility; and
3. lack of counterpart funds to meet part of the expenses of the items procured.

Executing agencies in the form of government departments exhibited varying degrees of efficiency during implementation. The variation in accomplishment of project objectives could be attributed to the degree by which:

1. the agency was committed to achieving the objectives of the project
2. the project matched changing policies and priorities
3. training programs included in the project were valued, utilised and well directed
4. staff were adequately trained, motivated and paid
5. staff assigned to routinely implement the project were aware of the objectives, scope, design, and eventual benefits to be expected, how these were to be obtained and their role in achieving these objectives
6. experienced staff from previous projects were assigned to later projects
7. the fielding of consultants coincided with project implementation and their expertise to local staff.

Failure to achieve the technical production parameters assumed at appraisal were mainly due to:

1. selection of beneficiaries whose animal management skills and resources were below expectations, resulting in poor feeding, handling, and disease control
2. selection of areas which had insufficient feed resources to support animal populations

3. over-investment in and poor preparation of animal importation, and introduction of animals unsuitable for the level of management skill of targeted beneficiaries; and

4. outbreak of diseases, which took a heavy toll.

As for project facilities, failure to meet their operational targets were mainly because:

1. facilities are over-sized, technically sophisticated and unsuitable to the capability of staff and systems and conditions under which implementing agencies are operating

2. preparation for installation (for example, selection and acquisition of sites, arrangement for electricity and water supplies) prior to importation and operation and management of the facilities, even though, in many cases, training was part of the facility supply contract.

**Future strategies for sustainable dairy development**

These experiences with livestock projects indicate that governments and financing institutions should be more cautious with investments in the livestock and dairy sector. More recently approved projects, of financing and funding agencies take into account such previous experience and many of the problems experienced by previous projects have been overcome. For future dairy development projects, the financing institutions and governments will have to adopt proper strategies in order to ensure their success. Moreover, future projects must take into account their sustainability beyond the investment phase.

**Sustainable development**

To achieve project sustainability, there are some minimum conditions that must be met:

- Sustainable projects should be self-sustaining projects, address a specific need, generate sufficient funds to provide participants with attractive returns over costs, meet their operating and maintenance costs and expansion needs, while preserving ecological balance and enlarging natural resources employed.
- Sustainable projects should be initiated by the beneficiaries in response to a perceived need. Their implementation is entrusted to members of the beneficiary group which provides dedicated leaders committed to the welfare of their community or group. These leaders should be financially accountable to their community.
- Sustainable projects should be flexible in scope, components and funding, and responsive to exigencies of changing circumstances during implementation.
- Sustainable projects should contribute to the development of the sectors outside project areas.

**Strategies for sustainable development**

Taking past project experiences into account, the strategies for developing sustainable projects should be to: (1) address macroeconomic policies and sector-specific institutional issues at the pre-feasibility stage; (2) address project-specific aspects at feasibility stage; (3) clarify the loan or assistance conditions, and set monitoring procedures and specific output targets at the appraisal stage; and (4) maintain flexibility during implementation in order to respond to changing circumstances. The factors affecting success of the past and ongoing dairy development projects which need to be addressed at various stages are elaborated
Macroeconomic policy environment

It is the macroeconomic policy environment within which dairy development is undertaken that largely determines success or failure. The conduciveness of macroeconomic policies determines the levels of appropriate technology and investment that the sector can sustain and hence the productive efficiency of dairy production. The main policy areas which should be established by each government include:

- level of priority accorded to the livestock sector by the governments and hence the degree of government commitment to livestock development
- clear definition of roles of the public and private sector in livestock development
- incentives provided to various elements of the industry particularly for large entrepreneurs who are actively involved in smallholder farmer livestock development;
- land tenurial rights for livestock raisers, both large and small
- levels of protection from unfair competition provided to producers
- pricing policy where the welfare of producers has to be balanced against the interests of consumers
- taxation, tariffs, and quotas on the imports of livestock products and production inputs which affect production cost and output prices
- interest rates, collateral requirements, the cost and efficiency of financial intermediation, and roles of NGOs in credit delivery
- conditions on import and export of livestock and livestock products; as well as
- religious and social factors, and condition of the environment.

Sector-specific institutional aspects

Among the important sector-specific institutional aspects which contribute to project success and sustainability, the following need to be established at the feasibility stage:

- technical, administrative, planning, management and monitoring capabilities of institutions in the sector
- efficacy of institutional inter-linkages between dairy agencies such as, extension services, veterinary services and research, as well as linkages with other institutions engaged in agricultural research, extension and support services
- complementarity between public sector services and producers
- degree of beneficial co-operation between producers, processors, and marketing organisations; and
- credit availability and efficiency of delivery, including those channelled through NGOs.

Project-specific aspects

At the micro level, project formulation for dairy development should ensure that:

- pre-feasibility studies are based on reliable data and a sound rationale for development
- executing agencies are suitably trained or could be trained in project management;
- credit and other service mechanisms are tailored to service potential sub-borrowers and beneficiaries in development target areas
- beneficiaries are selected according to their ability to undertake the project, and in particular their love of dairy animals and willingness to live and stay on farms at all times
- project participants possess or have the potential to organise themselves into viable production groups
there is a focus on production aspects, including, feed supply, animal husbandry, production of hygienic milk, and milk collection by farmers emphasising commercial orientation with strong participation of private entrepreneurship and co-operative attitudes

- a focus on the development of processing and marketing of dairy products where there is inadequate dairy processing capacities by the private sector, with participation of dairy farmers' organisations, to command a remunerative price for farmers

- development of dairy herds should be based on the species of animals which exist in the country concerned with, as much as possible, limited importation of livestock and genetic materials. There should be programs which build up supplies of dairy animals by non-dairy farmers within the country to support specialist dairy farming and to incidentally help increase employment and incomes of farmers in non-dairy areas

- there is a balance in project expenditure between the public and private sectors, and care is taken when suggesting that farmers or their organisations take a major share in upstream development such as large scale dairy processing facilities

- a balance is maintained between expenditure on supporting infrastructure and production facilities;

- specific needs are identified in consultation and in collaboration with project beneficiaries; and

- project output targets are clearly identified at preparation stage and monitoring and evaluation procedures are strictly implemented.

Specific conditions for internationally assisted projects

To ensure smooth implementation and success of a proposed internationally assisted project, requirements and conditions for project implementation such as incremental staff, counterpart funds, procurement and disbursement procedures, should be addressed thoroughly at the appraisal stage. This would ensure that government officials involved in project implementation are committed to accept such requirements and conditions. During the implementation stage, however, flexibility should be maintained by both the government and the assisting agencies with regard to those stipulated conditions and requirements as well as project scope in order to adequately cope with changing circumstances. Focus must be given to output targets.

Suggested Reading

Chapter twenty-two
Sustainability of smallholder dairy production
A.R. Egan

Introduction
The context of sustainability
Issues
Risk factors
Sustainability and carrying capacity
Sustainability and the feedbase
Sustainability and production per hectare
Sustainability and production per head
Waste management
Conclusions
References

Introduction

Dairy production systems range from large-scale, intensive, vertically integrated commercial systems to smallholder `subsistence-plus' income systems. This chapter concentrates on sustainability issues surrounding the opportunities and constraints for the smallholder dairy farmer.

There needs to be recognition of why we are advocating and working for the development of the smallholder dairy system. Economic rationalism sees no merit in a system that has no comparative advantage in the `global market'. The problem is that the millions of people we are concerned about have no access to, or cannot participate in, the market activities of the `global village' (De Boer 1985). The natural outcome of undiluted economic rationalism is unalleviated poverty and hopelessness for the powerless through institutionalised exclusion. Sustainable development issues relate to well-judged transitional and socially rational paths to an improved future in which `the transitional state does not become entrenched'. One question is `Sustainable for what period?' Is it until perhaps the specific system as a whole becomes redundant or counterproductive? For what period does a currently desirable smallholder dairy system need to exist and what is such a system evolving towards? How long should increasingly capital-intensive systems or replacement by imports be resisted?

There are probably many answers to these questions. This chapter, however, aims to point out that along the way, whatever the progression and inevitable sequences of change, the principles of sustainability must be observed, to avoid loss of resilience of the environment because it constitutes a key resource base for whatever will follow.

The context of sustainability
Smallholder dairy systems are capable of making an impact on a socio-economic sector principally defined within policies for alleviation of poverty and for increased local availability of high quality food produced from under-utilised resources. Successful strategies of small holder systems will generally avoid dependence on:

- expensive imports
- resources for which competition is ever increasing
- cash outlays against long delayed product output
- time and labour not consistent with other high priority demands
- complex equipment and highly specialised or complicated sets of technical skills.

Sustainability in such a system therefore poses complex political, socio-economic and educational, as well as technical questions. Briefly stated, the outcomes sought are:

- improved farmer lifestyle
- meeting community needs
- efficient utilisation of resources
- optimisation of feedbase production
- ensuring land and water resources are not degraded
- high conversion efficiency of livestock
- effective and reliable product output meeting demand and quality specifications
- sustained land use capability.

Long-term environmental objectives can be achieved only through consistent application of system-based strategies and appropriate technology on each individual farm. Success depends on setting those objectives in systems that are concurrently achieving realistically set production targets. Ideally the strategies should help enhance the capabilities of small production units and help improve matters affecting time of availability of resources. The question of sustainability, when taken together with the strategic constraints outlined above, demands that the totality of production, post-production and consumption systems be considered, addressing the microeconomic, social and ecological costs and benefits; not only now but well into the future.

In local dairy production and milk collection/processing/distribution systems, the current and changing context in a given locality needs to be thoroughly understood. This is because effects of different levels of competition and exploitation of resources set conditions for the relative impacts on the environment. There are different issues to be faced and options that can be acted on at the levels of individual farmer families, the local group of farmers collectively, and the wider `industry' in which they are participants. In some areas smallholder dairy farmers have great experience and the system has a level of maturity where community attitudes and practices are established and environmental impacts assessable. Elsewhere as new or more sophisticated systems are introduced, the effects have to be predicted and monitored to ensure the possibility for strategic corrections where practices are found not to be sustainable.

Widodo et al (1994a,b) provided a comprehensive analysis of performance of 274 well established small holder dairy farms near Malang in East Java. This provides a picture of the interlocking issues of sustainability. Their description and analysis identified farm size and feed supply as key constraints on returns to labour and investment. Limited feed supply led to decline in production, health and reproductive performance in cows. It also led to longer hours harvesting and transporting feed, with less time for cleaning, hygiene and manure distribution as well as less discrimination in harvesting and more harvest site damage. Lower performance of cows leads to reduced ability to service loans and to replace cows at the end of their productive life. Potential risks to sustainability then extend to any actions taken to increase feed supply, alter distribution of workload, or find ways of further exploiting the environment or
the animals.

To paraphrase the concepts argued by Preston (1990) and as in all farming systems, dairy production at smallholder level will only be sustainable if for each unit it:

- has a high degree of self-sufficiency and promotes self-reliance;
- optimises employment opportunities;
- does not contaminate its own or interdependent neighbouring environmental units;
- does not destroy or irreversibly degrade natural ecosystems.

Affordable, low risk strategies and management tools, together with education and co-operative action among smallholders, are also essential ingredients for sustainability of a smallholder dairy system. Optimisation of production within the above guidelines requires judicious increases in some inputs. Management practices should take into account potential impacts on the environment. Achieving acceptable levels of animal productivity with more animals in close contact will intensify the need for improved health and welfare practices. Stall and milking parlour hygiene, timeliness in conduct of daily tasks, animal and operator health and reliable milk quality interact with unit productivity as components of sustainability issues.

The aim is to optimise overall feedbase and livestock productivity from available natural resources through an integrated set of practices, making effective use of pastures, fodder crops, browse species, crop residues and by-products as feed, shelter and bedding; directly or indirectly providing sources of materials for soil amendment, fuel generation and recycling non-polluting waste to the land. All this is to be achieved in a system where smallholder dairy farmers' main concerns are:

- feed cost and production cost per litre of milk
- income from milk production and the roles and `fees' of middle men
- marketing practices and logistical problems of co-ordination
- roles of family members and family workload
- availability of services supporting farmers such as on-farm and regional demonstrations and training programs (Coung et al 1992).

In the wider sense the environment for performance is set both by farmer attitude and by policies of national or local authorities and the means they employ that encourage or discourage particular strategies and practices. Tradition, risk aversiveness, land tenure issues and the relationships between producer and the market chain are all-important. A technical analysis shows willingness to change to be related to:

- accuracy of identification and effective communication of the need/ opportunity;
- the demonstrable applicability and effectiveness of the practice or process involved;
- the ease of technical implementation.

Many of the principles and practices aimed at sustainability are consistent with modest productivity goals and with a core of traditional practices. There are however others that are alien and additional to basic production management. Even the distinction between the two is a variable depending on the community concerned. Of unquestionable significance therefore will be the outreach and educational programs and skill training that will underpin development of innovative programs that 'do the right things the right way for the right reasons'.

**Issues**

There is a view that nothing humans do to this planet is truly irreversible: recovery of the desired (original
or enhanced) ecosystem only takes technical knowledge, an uncompromising will to achieve and the assembly of whatever financial inputs are required. However, there are a vast number of situations where none of these requirements are met, so rehabilitation from a degraded state is not achieved. Even in the best of circumstances, there are effects of long term natural forces such as climate change and the relentless incremental land form changes under the impetus of gross erosive forces. These impose a form of change that can only, in part, be countered or delayed by adopting practices and moving to new patterns of behaviour that can for a period be gauged sustainable. The `cumulative effects of imperceptible change' are better prevented than reversed, and this can only be through small daily actions or management procedures calculated to avoid loss of productivity and land use capability. A significant factor is the large number of smallholders who are involved in actions that need to be concerted and well conducted if they are to be effective.

Natural disasters aside, perturbations to the ecosystem should not produce progressive and irreversible change in the resource base that reduces productivity of that land class. It also follows that actions taken in maintaining productivity (localised sustainability) should not deliver inputs on neighbouring systems that result in their deterioration. The ethics and policies of true sustainability are not to deliver the adverse consequences of our management practices on others, now or in the future. The factors involved are outlined in the box *Sustainability factors in systems development*, adapted from Egan (1997).

**Sustainability factors in systems development**

Land resources and impacts to be evaluated

- soil fertility
- soil type, structure, soil depth, soil biota
- plant water relationships, growth rate,
- soil mineral nutrient status, fertiliser use
- nutrient export, nutrient recycling, soil acidity
- surface water, runoff, silting, eutrophication
- ground water reserves, salinity, drainage
- slope, aspect, erodability
- plant cover of desirable species, persistence under grazing, cutting.

Annual cyclic phenomena to be matched:

- feed supply and quality
- plant growing season, pasture species, crop harvest residues, browse
- grazing management, conserved stored and treated materials, supplements.
- animal/herd cycles
- species, breed, sex, physiological state, and age groups
- stocking rate and grazing intensity
- effects of preceding conditions or performance on current capabilities.

Productivity and product quality effects to be assessed:

- skill and knowledge levels of operators
- resource requirements and availability, including timeliness
- meeting market specifications
- quality criteria
- reliability and timeliness of delivery
- achieving premium prices
Risk factors to be determined:

- changing competition for resources, resource costs
- increase in exploitation of resources, extra intensification costs
- variability in cycles, added costs
- flood/drought frequency, costs of strategies
- disease affecting mortality rates, production rates, quality of product
- product market movements in specifications, prices.

Risk factors

Sustainable strategies involve realistic assessments of limitations and vulnerability of the resources (inputs) and system-wide impacts as well as products (outputs), attempting to predict cumulative effects over time. Optimisation to achieve the best socio-economic outcomes involves recognising and evaluating risks and enabling the farmer to implement best practice for the purpose by assisting the development of management guidelines and tools. Given the incomplete knowledge of climate and the uncertainties that must exist, surprises cannot be ruled out. Nonetheless urgent attention to recognisable and manageable risk factors must be applied.

The characteristics of inputs and outputs of a production system are the main sources of the risks to sustainability, which are often less apparent than hoped. It is useful to consider them with processes in mind, as for example in Table 22.1.

The risk categories manageable at farm or farming community level are:

- carrying capacity: Stocking rate, over-exploitation of feedbase and natural resources
- feeding systems, productivity, product quality, and Greenhouse emissions
- production per hectare, intensification and despoiling the resource base
- production per head, animal health, welfare, life-time productivity, product quality
- waste management, utilisation, recycling and renewable resources.

Table 22.1. Example of inputs and outputs of a production system.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetics:</td>
<td>Physiology underlying productivity</td>
</tr>
<tr>
<td></td>
<td>Physiology underlying product quality</td>
</tr>
<tr>
<td></td>
<td>Resistance/tolerance to disease</td>
</tr>
<tr>
<td>Nutrients :</td>
<td>Feedbase and feeding systems</td>
</tr>
<tr>
<td></td>
<td>Sustainable bulk feed sources</td>
</tr>
<tr>
<td></td>
<td>Supplements: alternative sources</td>
</tr>
<tr>
<td></td>
<td>Feed evaluation</td>
</tr>
<tr>
<td></td>
<td>Seasonal reliability of sources</td>
</tr>
<tr>
<td>Housing:</td>
<td>Animal welfare, health and hygiene</td>
</tr>
<tr>
<td></td>
<td>Waste management</td>
</tr>
</tbody>
</table>
Sustainability of smallholder dairy production

<table>
<thead>
<tr>
<th>Health care:</th>
<th>Management and medicine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locality:</td>
<td>Land and water resources</td>
</tr>
<tr>
<td></td>
<td>Land use potential</td>
</tr>
<tr>
<td></td>
<td>Proximity to market</td>
</tr>
<tr>
<td>Labour:</td>
<td>Per day; per cow</td>
</tr>
<tr>
<td></td>
<td>Milk to market needs and specifications</td>
</tr>
<tr>
<td></td>
<td>Quantity per day; per cow</td>
</tr>
<tr>
<td></td>
<td>Quality hygiene, fitness for purpose</td>
</tr>
<tr>
<td></td>
<td>Timeliness</td>
</tr>
<tr>
<td></td>
<td>Offspring replacements, sales/loan conditions</td>
</tr>
<tr>
<td></td>
<td>Waste disposal and utilisation</td>
</tr>
</tbody>
</table>

Farm data relevant to these sustainability issues are scarce. Skunmun et al (1998) have provided insight into socio-economic conditions and farm practices on sample dairy farms in Thailand, in three areas described by them as ‘irrigated’, ‘municipality’ and ‘factory’ locations. The study forms a sound template for data collection covering many risk factors in the sustainability of smallholder dairy systems. In each area, milking cows were between 40 and 55 per cent only of the total herd. This typical structure contributes to higher stocking rates, high ongoing feed requirements and crowdedness of holding facilities. This in turn has adverse consequences for workload, hygiene and waste management.

**Sustainability and carrying capacity**

Productive animal numbers are limited to the constraints of feedbase and harvesting rates.

Top of the list for sustainability is a realistic production target. This requires assessment of local feed resources, potential production, harvesting efficiencies and feed conversion rates. The product of interest is milk but co-products are waste feed, dung and urine; dung as input for methane production to meet energy needs for cleaning, pumping and cooling as well as dung and urine as fertiliser for feed production.

Carrying capacity is the maximum population that can be supported indefinitely in a given habitat without permanently damaging the ecosystem (Rees 1990). Efforts to increase carrying capacity require careful audit of the impact on land and water resources. The local habitat is the first point of focus but the ecosystem expands beyond it to the catchment, the entire continental land mass and globally. Thus sustainability is a ‘think global, act local’ concept. Progress of a sustainable kind has more to do with earth stewardship than family net income, yet must be achieved in a world where there is an ongoing individual/family struggle for improved human dignity and/or financial status. Arable land is limited, and where food production increases pressure on land for increased production per hectare, in milk production, this increases the demand of individual animals for better feed supporting increased feed conversion efficiency. As other human needs encroach on arable land for housing and industry (rural land is urbanised) farmers close to market centres lose arable land. Crop production and animal production are intensified on the remaining land or expand/transfer into areas of lower natural productivity and potentially of greater vulnerability. Environmental issues arising with each of these changes results in catchment-wide problems in which smallholder dairying is increasingly vulnerable, not only to the environmental outcomes of their own activities but to those of others. Shared values, organisation and co-
Sustainability of smallholder dairy production

Sustainability and the feedbase

The development of a sufficient sustainable feedbase underwrites a sufficient animal feeding and health management system appropriate to local resources. The feed base for the smallholder needs to be quantitatively defined, feeding values assessed and guidelines developed for appropriate year-round feeding schedules. These are dependent on grazing or cutting regimes, fertiliser and water application systems.

Feed-year strategies involve matching target liveweight changes, reproduction and lactation performance with the changing availability of all sources of nutrients over time.

The tools for achieving change within a specific setting of feed availability ultimately work through processes of animal behaviour, rumen function, and physiology, and include those for:

- changing the animal production system or timing of events in it
- introducing pasture and fodder crops and food crops with different agronomic features giving more and better residues
- adopting different grazing, feeding and storage strategies and methods
- modifying crop residues by physical and chemical treatments
- changing feed availability, feed combinations, supplements and feeding procedures
- employing other technologies that enhance digestive and physiological performance.

Technical constraints encountered in the development of a feed year strategy are related to:

- the product(s) required of the animals
- the genetic make-up and physiological state of the animal
- the characteristics of the feeds available
- risk of mismatches in timing or location; and
- the storage, treatment and transport facilities available.

The animals' nutritional demands relative to the desired type, level and timing of product output (1 and 2 above) drive the search for options to optimise the feeding system (3,4 and 5 above) within the labour and capital constraints on individual farms. In dealing with these, some options come with added risks to sustainability and some threaten operator and animal health.

The feedbase options include some or all of the following: pasture of native grasses, self sown crop plants and weedy species, improved pastures, fodder crops, browse shrubs and trees, fibrous crop residues and `concentrates' from local agro-industrial byproducts. Supplements of N and minerals may be locally produced from fertiliser components and `block technology' is quite widely available (Leng 1992).

Sustainability and production per hectare

Inputs added are low cost, efficiently applied through practices that minimise risk of adverse effects to environment.

Production per hectare is a function of the quantity and quality of feed that can be grown. Increases rely on more inputs to improve plants and the environment in which they grow. Economic feasibility aside, if poorly managed extra inputs of plant nutrients can be the source of ecological damage or threats to quality
of water for cows and used in cleaning.

Both economic and environmental arguments have been used to support the contention that smallholders should be very sparing in their use of agricultural chemicals and devise systems that reduce rather than increase dependence on them. Marrying traditional management approaches with modern knowledge and selectively introducing appropriate new practices that are, to the best of our knowledge, truly complementary and supplementary is proving important. With small holder dairying, the experience of farmers is not uniform at the time they embrace the project of development. For some the entire enterprise is an innovation; for others, cows have featured in their system but specialisation is new. In development, it is wise to work with the farmer to devise a management system that can build on existing skills and experience. However when there is a substantial change in enterprise, the process is difficult. Traditional practices that in the past have had the desired effect, may not apply or may be based on concepts not compatible with the new directions needed. New skills and new reasoning are to be learned.

Animal production targets are constrained not only by the changing availability of capital, labour and the genetic and environmental resources available to dairy livestock owners, but also by the influence of others who share the ecosystem and social system in which they operate. For the individual farmer, the genetic potential or the physiological capabilities and the health status of cows are a primary consideration. However, the ability to do much about these is beyond the individual smallholder acting alone. Sustainability can then depend upon others to make the right decisions in ‘upgrading’ the dairy herd. Likewise, mismatches between feeds available and efficient cow performance may arise because of the actions of others and are often not in the power of the lone smallholder to correct.

Sustainability and production per head

Inputs are converted efficiently to desired products by adapted animals in systems where stress is minimised

In seeking higher production targets, animal genotype is often seen as the limiting factor. Experience with exotic dairy breeds has been uniformly disappointing in the circumstances of most small holder dairy systems. Numerous crossbreeding and selection programs such as those described by Mudgal (1992) have been undertaken with the objective of achieving the optimum balance of traits of indigenous and exotic breeds. However, any animals will perform well below potential wherever undernutrition or stress is present. Good stockmanship and concern for the well-being of the animal help identify stressors in the environment and reduce them or their effects. Feed and environmental conditions, such as ambient temperature, endemic disease and parasite problems, may limit performance of the genotype. Sustainability depends upon realistic appraisal of animal capabilities in the specific environment and of the extent to which management can improve that environment.

In a systems analysis, Mbuza (1991) graphically portrayed the consequences for sustainability in a comparison of indigenous tropical cows and cows with higher genetic potential for milk production. The consequences of feed inadequacy for animals of lower genetic potential may be a reduction or cessation of the already low level of milk production, and some liveweight loss, but fertility and health will be maintained. For cows of higher genetic potential, with a similar proportional reduction in feed the milk production will fall. The animal will also suffer substantial weight loss and loss of fertility.

Rising atmospheric methane levels and the contribution made to the Greenhouse effect is a global concern. It is estimated that in small holder dairy systems 15 Moles of methane is released into the atmosphere for every litre of milk produced (Obaidullah Khan 1992). Milk production per head is increased where feed digestibility, nutrient balance and intake are improved. These same circumstances
can reduce the rate of microbial methane production in the rumen. While improved feed quality may be a step in the right direction for both productivity and environmental objectives, these effects are minimal compared to what is estimated to be needed.

Animal health is invariably a matter of a whole management strategy with packages of practices to be adopted. Within those, where injections, vaccinations and drenches are required, the farmer should be able to use the latest and the best. If they cannot afford these for their animals there is a danger to sustainability as outdated practices and outmoded methods can pose the threat of breakdown in control of pests, parasites and diseases which can have far reaching consequences. Animals remain a reservoir for possible transfer and reinfection of others and can contribute to the phenomenon of development of resistance of the disease organism to the best practice treatments.

Whether exotic or indigenous, animals have a problem of heat loss which affects feed intake. Ambient temperature, humidity and metabolic inefficiency all contribute to this. Lowland high rainfall and irrigated systems may have the disadvantage of high ambient temperature and humidity both day and night. Cooling systems that rely on water use are vulnerable, and increase the risk of contamination of water supplies unless carefully engineered.

At higher altitude, lower night or day-round temperatures and lower humidity may have an advantage for the animal. Potential feed intake and level of production will be much higher. The issues about carrying capacity, land form, vegetation type and plant nutrient provision increase their significance. Sustainability questions therefore require a local resource and resource risk audit, particularly if an expanded or intensified industry is to throw increased or altered seasonal pressures on plant production - utilisation pattern.

**Waste management**

Outputs of wastes should be managed to minimise adverse effect and maximise beneficial effects in the production system and environment.

Good waste management is important for four reasons:

- maintaining quality of the milk product
- maintaining the health of the animals and the operators
- preventing adverse effects on land, water and plant resources
- exploiting wastes as an input resource.

Maintaining fertility of the land by return of dung and urine is traditional in most small holder systems. For specialised dairy units, some innovation is necessary to allow waste management without large capital outlay, on the one hand, and excessive demands for manual labour on the other.

In stalls, housing and milking parlours, or wherever the animals are confined, well-drained easily cleaned floor and bedding systems are essential. In terms of sustainability, easy recovery and distribution of dung and urine are important in small holder systems. Labour requirements, water use, pest and parasite control and milk hygiene are all elements linked to efficiency of cleaning.

Chantalakhana et al (1998) report on an investigation of the effects of dairy wastes on water and soil resources in three types of smallholder dairy systems. Their results showed that:

- waste water from older established dairy barns and crowded farms constituted greater risk to the environment because of higher COD (chemical oxygen demand), BOD (biological oxygen demand)
and presence of coliform organisms

- both waste water and leaching from piled and drying manure on bare land surfaces were implicated in ground water contamination
- waste water from the dairy barn, well water and public waterways in the locality all provided evidence of cumulative problems associated with lack of effective waste management practices and therefore are critical sites for monitoring
- monitoring of waste water can be based on relatively simple tests that correlate broadly with more sophisticated chemical and biological analysis.

The authors recommended, as a short-term solution, low cost sealed (cement) floors for drying manure, cement drains to deliver liquid waste into sewage tanks. In the longer term, delivery into central water treatment and/or biogas digester systems would transform polluting waste into a resource, but this requires co-ordinated action and investment on a community wide scale.

The quantities and qualities of manure and urine vary depending on the feed. A rule of thumb is that the lower the digestibility the lower the intake, the poorer the feed conversion to milk and higher the methane production per litre of milk, as well as the greater dung output per litre of milk. Improvement in digestibility and intake can be achieved by increasing cutting frequency and fertilising to increase leafiness and growth rate. However the higher N intake, the greater urinary N excretion rate, the more N to be recycled and the greater care needed in its distribution.

In some systems, effective use has been made of fermentable waste in small-scale methane generation. The simplest engineering systems of slope, drainage, solid and liquid separation and closed tanks with gas valves have seen methane available to heat water, generate electricity to drive pumps, all useful in dairy operations as well as the household.

**Conclusions**

Wherever small holder dairy farm systems have been introduced to serve a purpose for some (usually undetermined) time, the issues of sustainability remain basic: if practised, the 'best practice' serves both the ongoing health of the dairy system and the resilience of the environment for any system that supplants it. High cost inputs are beyond the small holder but strategic use of low cost inputs to raise efficiencies and product qualities can be more consistent with sustainability. Assessment of carrying capacity and setting realistic production goals to be met from fewer rather than more animals allows guidelines to be set for sustainable systems. Available feed resources are usually limiting, so conservative stocking rates, sensible year-round feed plans, and grazing, cutting and manuring regimes to sustain high plant growth rates for the main feedbase allow realistic upgradings of production goals to be achieved. In each of the areas of input affecting milk production and milk quality, risks have been identified. While more systems need to be monitored to support the contention, pressure on smallholder families to improve their financial situation can result in counterproductive actions and this may be where threats to the ecosystem are most likely. In these cases guidelines, practices and tools developed with the farmers will be essential. Perhaps understandably however, knowledge of the risks to ongoing production will play a more significant role in their compliance than abstract reasons related to health of the ecosystem.

**Reference**

Feeding. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. pp. 15-20.


Bangkok, Thailand. pp. 3-6.


Dairy cattle kept in extension to a family house, with possible risks to human health.

Rearing dairy cattle adjacent to public waterway, Nong Pho, Thailand.
Cattle manure spread out to dry.

Waste water and slurry draining from cattle housing into neighbouring areas, with potential risks to human health.
Chapter twenty-three
Research priorities for smallholder dairying
C. Chantalakhana

Problems and constraints of smallholder dairying
Institutional support
Technical factors
Government policies
Socio-economic factors
Dairy research priorities concerning technical factors
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Problems and constraints of smallholder dairying

In spite of several decades, or centuries for some countries, of dairy farming in developing countries the productivity of smallholder dairying (SHD) has remained at a relatively low level due to a lack of appropriate dairy research (Chantalakhana 1995a). Furthermore the science and technology available in developed countries cannot be readily adopted by small farmers due to their socio-economic and agro-ecological conditions being greatly different from those in industrialised countries. Some dairy technology developed in advanced countries may be appropriate for adoption by smallholder dairy farmers but most of these dairy technologies or dairy practices have never been transferred to smallholder farms due to a lack of effective extension services.

It is obvious that not all problems related to low productivity of SHD can be solved solely by research solutions. They are also influenced by other factors such as unfavourable government policies, lack of market outlets, and inefficient dairy extension services. To understand the relationship of research and development activities for SHD improvement, which will systematically lead to more effective identification of research priorities, it is important to analyse related factors which influence the SHD systems. Figure 23.1 presents a holistic picture of factors which may influence the productivity level of SHD. It can be seen that there are many factors which influence a SHD farmer, for example, whether to invest in SHD, what scale of operation and the type of technologies to be employed or adopted. Once a SHD farm has been set up, the level of productivity then depends on many additional technical and socio-economic factors. For convenience of discussion, the influencing factors as presented in Figure 23.1 are classified into four categories: a) technical components, b) institutional support, c) government policies, and d) farmers' socio-economic factors. A lack of any of these supportive factors could become a
constraint on the level of achievement of any dairy development programme.

**Figure 23.1. Factors affecting SHD productivity**

**Institutional support**

Examples of the institutional support required to facilitate dairy industry growth include credit institutions, farmer-training facilities, milk collection centres, processing and marketing facilities, dairy farmer co-operatives or groups, and research and extension services. Most SHD farmers have limited financial resources and depend mainly on bank loans for farm investment. These farmers have little formal education and limited knowledge of dairy husbandry. At least two to three months of intensive practical training is required to provide farmers with a reasonable technical background in dairy farming. A milk collection and cooling centre is required, to collect milk from SHD farms and then transport it to a milk processing plant for processing, packaging, and marketing the products.

**Technical factors**

Prerequisite technical factors consist of; (1) suitable dairy breeds for hot and humid tropics, (2) availability of good quality feeds especially roughages, as well as clean water, (3) good farm management practices and herd husbandry, and (4) appropriate control and prevention of tropical animal diseases and parasites. These factors are well recognised in general and have been extensively documented.
Dairy extension services provide artificial insemination, health care such as vaccination, and other services which are constantly required by farmers to improve their farming efficiency. Research on various aspects of dairy production including socio-economic and policy studies is required to isolate constraints to further improvement in SHD. Government departments and universities need to be well equipped with dairy research facilities and technical and social research skills to be able to conduct research. The lack of effective dairy extension services and adequate research support appeared to be the two major constraints in dairy production (Chantalakhana 1995a).

**Government policies**

Expansion of dairy development could benefit from related government policies conducive to dairy farming. For example in Thailand, some changes in government policies have produced major positive impacts on dairy production, such as; (1) the Regulation of the Ministry of Commerce (1985) on Dairy Products Manufacturing, which requires producers of recombined milk to use fresh milk to recombine milk at the ratio of 1:1 or 1:20 of skimmed powdered milk (kg) to fresh milk, (2) a milk drinking campaign sponsored by government to increase fresh milk consumption from about two kg per capita to 15 before the year 2000, (3) a school milk program launched during 1994-95 to promote milk drinking among pupils outside urban areas in order to improve children's health, (4) diversification of rice production to dairy farming in order to reduce paddy farming in certain areas.

Other government policies which may have a serious impact on dairy production include, GATT or free-trade policy requirements, the establishment of a Dairy Board to promote the dairy industry, as well as government support to strengthen the dairy extension and research system.

**Socio-economic factors**

Certain socio-economic factors, such as, income from off-farm jobs, availability of capital, milk prices, price of land, farmer education and training, and availability of family labour, influence a dairy farmers' decision on whether to expand and improve dairy operations. A number of farmers undertake dairy farming as a secondary career, while either the husband or wife has another job in town. Some farmers may work in the policeforce, teaching or driving trucks, while their partner runs the dairy farm. The price of farmland in many Asian countries has increased in recent decades. Some farmers sold off part of their land for cash, reducing areas available for forage plots and, hence, increasing the pressure on farmers' management skills due to a lack of good quality roughages for dairy cows during the summer months. The scarcity and cost of hired labour can also be a problem, when children with higher education find excitement in the city and never return to farming. The price of milk is usually indirectly regulated by some government measures; farmers have argued that milk prices are low and not profitable due to the rising cost of animal feeds, labour and transportation. However, at the same time the retail price of milk is high, usually two and a half to three times the farm price, which reflects high marketing and packaging costs as well as a substantial market margin.

**Dairy research priorities concerning technical factors**

The efficiency of milk production (E) is a function of income from farm outputs (A), mainly from milk sale, and costs of farm production (B). In this way, the efficiency (E) of a dairy farm can be calculated as (A-B)/B or profit per unit of costs. Therefore, in order to increase the efficiency of SHD one needs to increase A and reduce B. In order to increase milk yield per cow, one has to choose dairy cows with high genetic potential for milk production. It is obviously more profitable to raise a cow with an average milk yield of 16 kg per day as compared to one with and eight kg average milk yield. Most SHD farms in the tropics produce on average only seven to eight kg of milk per cow per day. High milk yield from high
producing cows can be realised only when well fed and cared for. Dairy cows have to be bred to conceive within two or 2.5 breeding services, as a longer breeding interval will result in a long calving interval (CI) which will reduce production efficiency. Hence, the aspects of reproductive efficiency and fertility in dairy animals are very much related to milk production efficiency, that is, in terms of milk production per day of calving interval (Chantalakhana 1995b). It is clear that a cow producing 3200 kg milk per lactation with 400 day CI (eight kg milk per day of CI) is more profitable than a cow with 3500 kg milk but 500 day CI (seven kg milk per day of CI).

The other aspect of increasing SHD efficiency (E) is to reduce production costs (B). Most milk production costs are related to feeds and feeding (65 to 75 per cent of milk production costs). Ruminant feeds consist of concentrates and roughages. The ratio of feed costs for concentrate: roughage on SHD farms generally ranges from 1:1, during seasons when roughage supplies are readily available, to 1:2 when prices of roughages increase due to limited supply. Another way to reduce B is to reduce the proportions of replacement animals in a dairy herd. In general, the percentage of replacement animals on SHD farms usually range from 40 to 45 or from 45 to 60 per cent when including dry cows. These are non-producing animals and should be reduced as much as possible in order to minimise maintenance costs of the herd. It is also important to reduce losses in the herd due to health and management causes in order to reduce B and/or increase A. Research priorities to increase A and reduce B in order to improve SHD production efficiency are discussed in detail in the following sections.

**Research priorities in dairy feeding**

One of the most common problems facing SHD farmers in the tropics is the scarcity of good quality roughages during the dry or summer season. Most farmers have to use whatever sources of roughage are available for dairy feeding, sometimes at very high prices. These sources of roughages consist of (1) agricultural fibrous residues or by-products such as rice straw, corn stover, soybean stems, pineapple peel and sugarcane tops and (2) forages or fodder leaves either produced on the farm or collected from outside the farm. There are many researchable areas concerning these feedstuffs; (1) how to make best use of these sources of roughages through knowledge of their nutritional composition, (2) how to prepare and feed these roughages to dairy cattle so that they receive sufficient feed intake to satisfy their body functions, (3) the appropriate tools and methods to collect and store crop residues available on small crop farms at different locations, to be able to maintain sufficient roughage supplies and quality for dairy feeding in the dry summer months.

Forages and fodder leaves available in limited quantities are usually cut-and-carried for dairy feeding in the dry season by individual SHD farmers. Hay and silage for dairy feeding are well known in developed countries but are often not practical in developing countries because most dairy operation is in SHD farms with small plots of land. Operational research on how to produce hay or silage on a commercial scale as a separate enterprise in order to provide roughage feeds for sale to SHD farms is required. It is also very important to study practical, economic, and commercial aspects of producing certain crops, such as sugarcane, rice, or corn, for dairy feeding.

Commercial feeds for dairy cattle which are sold in developing countries are generally formulated by being based on feeding standards and animal nutrient requirements, developed in temperate countries such as the United States and United Kingdom. It is necessary to study the feeding requirements of dairy cattle in the tropics to be able to formulate the most suitable and economical rations for SHD farms in each major environment. Non-conventional sources of concentrate feeds, for instance by-products from soybean product factories, oil palm cake, or other industrial by-products, may be available for dairy feeding in certain areas. Such feedstuffs require research about quality and methods of utilisation as animal feeds. The problems of mineral deficiencies affecting milk production and reproduction have been common issues for SHD farms in the tropics. Development of mineral supplements in order to prevent...
Research priorities for smallholder dairying

Mineral deficiencies due to poor quality roughages is also needed. A summary of research priorities in dairy nutrition is presented in Figure 23.2.

Research priorities in dairy breeding

Most dairy cows in tropical countries produce an average of seven to eight kg of milk per day, while many high producing cows in local breeding programs can produce 15 to 20 kg of milk per day. These production figures clearly indicate that with effective selection and culling programs the productivity of dairy herds can easily be improved. One of the most serious problems in dairy selection in developing countries is the lack of a milk recording system on SHD farms. Technical studies are needed to develop appropriate and economical systems of milk recording, in order to allow performance evaluation of an individual cow and thus helping decide whether to cull or keep the cow in the herd. Expertise and knowledge from developed countries can be examined and adapted to improve SHD in developing countries. Schemes for progeny testing of local bulls, crossbreeds or high-grade cattle, should be implemented for long-term breeding improvement of local dairy herds. Computer programs or software for genetic evaluation of animal performance with different sets of milk records need to be modified to suit routine use. In order to improve dairy productivity in the long term, genetic selection programs need to be carried out at the national level in each country. Incentives for SHD farmers to cull low producing cows is also an important for research investigations in order to determine socially acceptable means of improving genetic selection.

A long-term systematic breeding program at the national level in order to improve dairy productivity on SHD farms, should be organised, along with a milk recording system in each developing country. In order
to involve and make use of genetic stocks on SHD it is often recommended to employ an open-nucleus breeding system (ONBS) with the use of MOET (multiple ovulation embryo transfer) for dairy genetic improvement in developing countries (Hodges 1990). It has been calculated that for pure-bred dairy breeding, as tested in some developed countries in Europe, the ONBS/MOET yielded higher genetic gain with a shorter generation interval compared with regular progeny testing. An ONBS scheme is presented in Figure 23.3. The ONBS/MOET has not been implemented or studied in developing countries so far, where dairy populations are mainly Holstein-Friesian (HF) crossbreeds, except India. It would be very useful to organise such a scheme based on continuing or future government dairy breeding programs. This would assist the investigation of actual genetic progress and problems which may arise due to ONBS operation under the less favourable technical conditions of developing countries. This type of operational research requires long-term planning and re-organisation of government dairy breeding activities, mainly involving existing resources and facilities, in order to avoid substantial research investment. Further training of technical personnel involved in the ONBS/MOET program is very important, including knowledge of MOET/AI techniques, dairy recording systems, and concepts of ONBS.

With the availability of some advanced biotechnological techniques, at present and in the future, there will be many areas of research in the molecular genetics of dairy cattle in the tropics. Research into specific disease or parasite resistance in some indigenous cattle, for example, resistance to tick fever in some local cattle breeds in Asia, or resistance to trypanosomiasis in N'Dama cattle in Africa, requires special technical interest. Studies on genetic aspects of adaptation traits in tropical breeds of cattle under hot and humid conditions will also be of future importance. A schematic summary of research priorities in dairy breeding and genetics is presented in Figure 23.4.
Research priorities in dairy management and health care

Knowledge concerning dairy herd management such as barn types, feeding methods, waste management, and calf feeding and care, in relation to tropical conditions, is lacking. Western technologies in these areas have been proven to be mostly impractical for developing countries, due to differences in socio-economic and climatic factors. Improvement of dairy management practices requires much research and would prove profitable to SHD farms. Many problems related to herd management contribute to low reproductive efficiency in dairy cows, problems of mastitis, and low milk quality, which eventually cause low productivity of SHD.

Diseases and parasites are a relatively larger problem for SHD in the tropics. Diseases, such as, foot-and-mouth disease (FMD), tuberculosis, and foot rot are more common on SHD farms. Flies, ticks and other insects are more prevalent in the tropics, as well as internal parasites, such as, liver fluke, round worm, and others. In relation to animal health problems, methods of disease diagnosis are a very important area of research. For infectious diseases like FMD, epidemiological research deserves high priority in order to implement effective control and prevention measures.

Problems with mastitis and reproduction in dairy cattle are mainly related to animal management, feeding, milking, and health care. Other factors which contribute to these problems are genetic, physiological, or pathogenic in nature. Hence, solutions to these problems have to take a holistic approach and start from farm practices by farmers. To reduce the incidence of mastitis and increase the reproductive efficiency of dairy cows, known dairy management technologies should be transferred to individual farmers. Research into methods of transfer of such technologies to dairy farmers deserves high priority. Experiences indicate that with effective transfer of existing technologies, such as mineral supplements, appropriate feeding, and health care, reproductive efficiency in dairy herds can be greatly improved. For relatively larger dairy herds, the use of a computer-assisted herd-health program can substantially improve farm efficiency. Figure 23.5 summarises some research areas in dairy management and health care.
Dairy research priorities concerning socio-economic factors and policies

Figure 23.6 presents some research areas related to socio-economic factors and government policies which influence SHD farms in developing countries. At farm level there are many factors, such as technology adoption, farmer training, and off-farm or non-farm income which may affect farm productivity. The issues of gender roles and women in dairying, youth educational programs relevant to dairy production, and the quality of life of dairy farmers, are related to the sustainability of dairy production at farm level.

Farmer organisations such as dairy co-operatives are important for SHD development. The milk collection and cooling centre, feed mill, AI service, milk processing and marketing all have to be well organised in order to promote SHD. These business enterprises can be operated by a dairy co-operative or farmer association. In developing countries, dairy co-operatives are not usually very strong in business operations. It is important to assess of existing farmer organisations and determine methods to strengthen them. Many areas of research developed to improve the efficiency of farmer organisation are shown in Figure 23.6.

Figure 23.5. Schematic summary of research priorities in dairy management and health care.

Research into dairy production systems concerning, economic aspects, constraints, future trends, environmental impacts and sustainability, as well as, alternative dairy production systems, deserve high priority. Studies of dairy marketing in relation to marketing of raw milk and processed milk, consumer requirements concerning health or food habits, and future demand and supply are particularly important.

Government policies can impact on SHD development. Government dairy promotion programs and extension services can assist the initial phase of dairy development in most developing countries. Once a SHD farming program has been well established, the role of governments should be progressively replaced by the private sector livestock services for all but essential regulatory activities (De Haan 1995). During recent years the issues related to GATT/WTO and its implications on SHD farmers have received much attention. So far it is not clear as to the mechanism and degree of impact of GATT/WTO requirements on SHD farms.
Appropriate technologies for smallholder dairying (SHD)

It is important to re-emphasise that any dairy science and technology developed by research workers for SHD farmers' use, must be appropriate for SHD farming conditions in each location or country. In other words research for SHD must recognise the smallholder farmer and farming systems perspectives. In this way SHD farmers should be allowed involvement and participation in all possible steps of the research process.

In the past, smallholders adopted technologies developed by researchers in developing countries at very low rates. This may be related to those animal scientists having been trained in conventional commercial production with no chance of, as well as no interest in, being exposed to small farm production and problems. Table 23.1 shows a case study of the extent of adoption of different animal science technologies by small-scale farmers in Thailand (Chantalakhana 1990).

![Diagram of Socio-economic factors and policies for smallholder dairying]

The most common rates of adoption by small-scale farmers who raised bovine animals in Thailand were
zero to one per cent although crossbreeding and selection of draught animals were in the range of 11 to 50 per cent, as was the use of fodder and forage crops and vaccination against certain infectious diseases. Castration, mostly by traditional methods, of animals used for draught was widely practised. Artificial insemination has become a general breeding method in dairy production, but has only been adopted to a limited extent for beef cattle (one per cent) and buffalo (less than one per cent). Embryo transfer has been a favourite research subject, mainly due to the availability of external funding, but only a few dairy calves have been produced in this way in the past. This is due to the cost and the technical requirements being too high for any possible benefit.

**Table 23.1. Use of some well-known animal technology by small-scale farmers in Thailand.**

<table>
<thead>
<tr>
<th>Animal technology</th>
<th>Practised by small-scale farmers raising bovine animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrition</td>
<td>0-1% 1-10% 11-50% &gt;50%</td>
</tr>
<tr>
<td>Straw chemical treatment</td>
<td>x</td>
</tr>
<tr>
<td>Mineral blocks</td>
<td>x</td>
</tr>
<tr>
<td>Pasture</td>
<td>x</td>
</tr>
<tr>
<td>Fodder/forage</td>
<td>x</td>
</tr>
<tr>
<td>Concentrated supplements</td>
<td>x</td>
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<tr>
<td>Breeding</td>
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<tr>
<td>Crossbreeding</td>
<td>x</td>
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<tr>
<td>Selection</td>
<td>x</td>
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<tr>
<td>Maintain breeding bulls</td>
<td>x</td>
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<tr>
<td>Physiology and AI</td>
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<tr>
<td>Oestrous synchronisation</td>
<td>x</td>
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<td>Pregnancy test</td>
<td>x</td>
</tr>
<tr>
<td>Artificial insemination (AI)</td>
<td>x</td>
</tr>
<tr>
<td>Embryo transfer</td>
<td>x</td>
</tr>
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<td>Management</td>
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Colin McClung accurately noted:
`...Science has much to contribute to these farming systems. But to do so, researchers must be unusually adept at seeing the world from the farmer's vantage point.' (Harwood 1979).

Today, serious problems arise from the fact that most researchers have not yet developed `eyes' to be able to recognise, and `ears' to be able to listen to and understand, the situation as it appears from the farmer's point of view.

One research approach which offers scientists an understanding of farmers' perspectives in planning and conducting research is the Farming Systems Research (FSR) Approach. The aims of FSR are to generate appropriate technology for small-scale farmers, and where possible, to improve policies and support services for farm production, in order to improve farm family welfare, and to enhance society's goals (Palanothai 1985). This approach views each farm in a holistic manner, and considers the farm as a total system, taking into account the physical, biological, and socio-economic factors affecting the farm, and recognises the interactions between these factors.

Farmer science

In general, small-scale farmers in developing countries have many important features in common, for example, limited physical and financial resources, funds, subsistence production, and limited education. On the other hand, they differ in many ways, such as culture, traditions, beliefs, farming practices, soils, rainfall, and marketing conditions. Therefore a technology successful in one location may not be accepted by farmers in another location or even by different farms in the same location. It is also found that technologies not adopted by farmers at one time, may become widely used after changes in economic or other conditions.

Strengthening of national research and international collaboration

While international research is a vital part of the total package for the improvement of smallholder animal production, it is national efforts in research which must provide the location-specific perspective. An effective `critical mass' of researchers in national systems must be trained or retrained by research institutions so that their activities are oriented toward small farm development. Both scientists and technicians who are well trained in research procedures and understand small farm systems are greatly needed in developing countries. Research facilities and infrastructure also have to be made available to national systems. International support to develop manpower for research on smallholder animal production will, in the long run, have significant impact in terms of increased food production and income in rural areas of the Third World.

Another way of strengthening national research systems is by better information exchange, through the collection and dissemination of research information, technical meetings and seminars, networking of research staff in various countries, and training in specific research methods.

Recent developments in the field of biotechnology have aroused much interest in scientific communities in developing countries. Some biotechnology may be used as a tool by scientists to enhance or accelerate the improvement of smallholder animal production, such as in the fields of vaccine production and nutritional improvement. It is not economically justifiable for developing countries to begin research into biotechnology without clear and specific research priorities for results which will be of immediate use for the well-being of their people. However, it is necessary for scientists in developing countries to be kept well informed of new developments in this field. They should also be trained to use certain aspects of
well informed of new developments in this field. They should also be trained to use certain aspects of biotechnology in their research. Hence, some kind of international mechanism should be organised to provide this kind of service for developing countries. There are also many other research tools and methodologies, about which scientists dealing with smallholder animal production must be informed.

Another approach to strengthen national research is through collaborative activities. Conservation and improvement of animal genetic resources is a good example of a field where national research could be strengthened through collaboration. Identification and evaluation of crossbreeds and exotic breeds in different environments can be done efficiently by national scientists. There are also other international research activities which can best be carried out through collaborative efforts involving both national and international systems.

References


Chapter twenty-four
The future for smallholder dairying
L. Falvey

Introduction
Smallholder dairying has been defined in terms of numbers of animals per producer, the resources available to an individual producer, and as a component of an integrated farm and an integrated dairy industry. In postulating the possible future for smallholder dairying, it is necessary to acknowledge variations between individuals and groups of farmers, countries and regions, and the impact of such diverse factors as dietary preferences, alternative occupations, colonial heritage, trade regulations and subsidies. Assessments of international development agencies such as the World Bank and the Asian Development Bank have largely rested on assumptions that smallholder dairy producers in developing countries in some way mimic smallholders in the past, of more developed countries. In some cases, they assume that smallholders will evolve into larger producers in free market environments. Conclusions for the future of smallholder dairy producers are then based on a gross comparison of natural resource endowments. The current competitive advantages of temperate climates are commonly extolled as the primary, and in some cases, the sole reason for suggesting that smallholder dairying in the tropics cannot be a viable industry in the long term. Our conclusion is contrary to these assertions; we believe that it has a sound future. To elaborate this conclusion, some of the critical points made in each chapter of this book need to be linked together to describe the forces which will determine the future of smallholder dairying in the tropics.

Forces for the future
The future of smallholder dairying in the tropics will depend on its past and current status in an area, the application of known and future technologies, and international attitudes to assistance and marketing.
The future for smallholder dairying represents a niche which has survived and developed despite a reticence for specific assistance from development agencies. The continuing global forces on the dairying industry, as for other industries, seem to be creating larger processing companies which create the market for fresh milk. However, the same global forces are also creating a niche for low cost producers of milk. This produces opportunities in developed countries such as New Zealand and Australia with benign climates which allow year-round pasture-based dairy production to produce low-cost milk. In different production systems, and in less benign climates of the tropics, low cost production is related to the inherent poverty of individual producers and their ability to utilise by-products in a manner more intensive than could be common place in more developed countries. Stimulation of this niche market, should it have developed in a western context, might be seen as a boutique market.

This boutique market is developing predominantly in Asia, to an extent in Africa and also in Central and Latin America, under differing production systems, using different mixes of milk producing species, and in different social environments. Limitations exist in socio-economic terms such as investment capability, time availability, knowledge of postharvest handling of milk, and inability to access or demand support services. Nevertheless, within these constraints, smallholder dairying continues to flourish. The environment in which it flourishes is characterised by diversity of production systems, social requirements and by the special stresses introduced by tropical environments. These include not only temperature and humidity effects but also the associated occurrence of diseases and both external and internal parasites.

Management around social and environmental limitations has been the key to success of smallholder dairying industries in the past as it remains at the present time. The future will rely on continued adaptation of management techniques to suit markets, environments and socio-economic conditions. In the case of the physical environment, selection of stock suited to individual environments and management systems is critical. Just as countless generations of selection have gone into producing stable breeds in India and some other traditional milk producing nations in the tropics, so a continued focus on breeding will be important. As distinct from the past, the use of new techniques and knowledge in upgrading will allow the production of suitable animals from crossbreeding of local with temperate dairy breeds, crossbreeding of local with locally improved dairy breeds, and selection within local breeds. The use of buffalo for milk production in India may in fact be seen as a broadening of the concept of selection. In that case, `selecting' a different species and then selecting for production characteristics within it allows the production of milk from a wider range of physical environments associated with socio-economic demands for other outputs, such as draught and meat. Emerging technologies such as embryo transfer, while talked about often, are not an essential component for the immediate future of development of appropriate breeds for smallholders in the tropics. Artificial insemination, which has been proven to be widely applicable does, on the other hand, permit rapid upgrading of breeds. However, such programs can only be evaluated in terms of sustained milk outputs from a herd or a breed and therefore cannot be undertaken efficiently in the absence of herd recording systems.

Specialist management of available resources in smallholder production systems in the tropics allows milk to be produced on a low cost basis. Output of milk per animal is low although when analysed on a cost benefit basis, the use of by-products or waste as feed, and other benefits such as draught and meat production, the efficiency of smallholder production systems may be seen to outweigh the efficiencies of dairying mono-cultures. However, such comparisons are less important than the aspect of choice of alternative product output in each situation. Smallholder dairy producers, in common with large holder producers in more developed countries, continue in an industry because it is the best economic alternative.
feed, nitrogen balance, and maintenance of animal condition to suit both draught and milk output, provide further means to enhance the efficiency of smallholder dairy production.

Integration of dairy farming with crop production systems, particularly in Asia, defines smallholder production in a specific manner which is not widely understood in mono-cultural dairy production systems. Breaking an integrated farming system into individual components is only important in terms of providing an understanding to those analysing a system, be it for research purposes or to familiarise themselves with a new production system. A model of an integrated farming system will provide an indication of the incremental benefits provided through dairying as an adjunct to cropping, draught, meat, pig production, and a range of other farm-based enterprises. However, it will not facilitate a simple economic rate of return analysis as if all input resources are allocated to a particular industry. Nevertheless, an understanding of pasture management provides scope for increased levels of feeding efficiency within both integrated and separated dairy production systems. Utilisation of such technology has been largely restricted to State farms in the tropics and it is now slowly seeping through to smallholder farms, thereby allowing preservation of fodder during seasonal production periods through such products as hay and silage.

Further production increases in smallholder dairying are also indicated through the application of special care in management. This can be broken down into practical steps for use with animals and each physiological stage of growth and production. Likewise breeding and reproductive management becomes an essential component of improving production from smallholder-based systems through increased calving and survival rates and reduced numbers of followers which must be maintained in a herd. While certain animals maybe retained on smallholder farms for social reasons or even reasons of personal attachment, it is wise management to be honest about such decisions.

Management of milking itself, a commonly overlooked area, also provides opportunities for increased yield and improved animal health. It is of particular interest that milk harvesting from high performing cows can be improved through increased association between milkers and cows; a simple factor of putting a cow at ease to let down more milk. The application of such a simple management tool in smallholder situations is common, although in areas where dairy development is a relatively new phenomenon such associations require further emphasis.

External factors affecting smallholder dairying industries in the tropics include changing international marketing arrangements for milk products among other agricultural commodities. This should create further opportunities for smallholder dairying within local areas, although one would be hard pressed to see smallholder dairying in the tropics develop into a significant export industry. The experiences of financing agencies in supporting livestock projects indicate that dairy projects in particular, produce most discouraging conclusions. In assessing the range of evaluations conducted by these agencies, it is noteworthy that the focus on outputs is related to those defined at the time of project appraisal and that project appraisal commonly assumed that dairy industries would develop on a basis similar to that of more developed countries. A focus on animals and investment in smallholder dairy production conflicts with the logical focus which is the smallholder.

Having defined a continuing role for smallholder dairying in the tropics with potential for significant increases in efficiency and expansion, sustaining such an industry must also be considered. It is clear that many production systems in highly populated areas may prove unsustainable and that these can be tolerated in the short term to overcome peaks in human population growth. However, integrated farming systems provide for circulation of nutrients with high efficiency while minimising a build up of toxic products in any one area. The relative absence of reliance on important inputs further minimises the danger of contamination within such systems. Depletion of the natural resource base is the primary concern with respect to sustainability and it would appear that systems developed in integrated dairy
production in such highly populated areas as Indonesia, China, Vietnam and India provide an indication of the probable sustainability of these systems. Dairy industries in more developed countries may be less sustainable.

The future for smallholder dairy development will rely on continued research and education of smallholders themselves. Research needs to challenge existing assumptions and acknowledge integrated systems and the central role of smallholders while focusing on technical parameters of breeding systems, herd recording, feeding systems, production of breeds, the multiple uses of animals, management of reproduction and health, and milk harvesting systems. The strong social research requirement of smallholder dairying in the tropics contrasts with that of dairy research in more developed countries while the technical elements share common scientific bases. The future for individual countries in smallholder dairy production is likely to vary according to the stage of development of a country, the relative levels of market protection, and an understanding of smallholder dairying by international development agencies.

Modelling smallholder dairying

A model for developing smallholder dairying in the tropics would include variables relating to:

**Feeding systems:** crop residues; pastures; communal pastures; concentrates; preserved pasture; supplements

**Breeding systems:** local breeds; local breeds crossed with temperate dairy breeds; local breeds crossed with local dairy breeds; near pure bred and pure-bred temperate dairy species

**Production systems for fodder:** specialist fodder producer; production of own fodder; roadside harvesting; communal management

**Stimulus for development:** development banks; local banks; government programs; aid organisations; local initiatives; non-government organisations

**Physical environment:** wet tropics; dry tropics; high altitude; low altitude; rainfall distribution; temperature variations

**Management:** epidemic disease management; herd and individual animal management; housing; feeding for production; private services for animal health; production systems; milkers as specialist service providers

**Applicable technologies:** herd recording; by-pass protein feeding; urea and alkaline straw treatments; vaccination programs

**Milk market:** local fresh milk; local pasteurised milk; export from local area; processing for local boutique markets; selling to large factories; domestic use; mixing with imported milk powder

**Processing:** village level; area collection and processing; factory-based; multinational factory-based

**Integrity of dairy system:** specific dairy enterprise; mixed farming enterprises; adjunct to other farming activities; adjunct to other wage earning activities; fully integrated with farming system

**Multiple animal outputs:** draught; meat; asset management; religion; status

**Sustainability:** short term; medium term; long term; comparison with other food production enterprises;
comparison with dairy sustainability in other countries

**Animal species:** cattle; buffalo; goats; sheep; other

**External environment:** implications of GATT; policies of financing and funding agencies; involvement of multinational processing facilities; local ability to collectivise

**Land ownership:** landless; own land; own dairy-shed land; utilisation of farming in conjunction with communal land; communal grazing; family assets; migratory production

**Outputs:** raw milk; family security; income; infant and family nutrition; marginal incremental output to an integrated system; benefits from animal manure for cropping; maintaining additional animals for work; meat consumption; additional animals for sale.

Incorporating all of the above factors, which are in themselves not exhaustive, into a single model would be complex and of primarily academic interest. Models which characterise individual production systems while acknowledging the key aspects of; existing and new technologies, adoption of technologies, marketing systems and constraints, socio-economic constraints and environmental factors including feed availability, will ultimately be of maximum benefit. Such an approach should be encouraged in each situation where external investment is contemplated. It is not sufficient to assume that dairy advisors from developed countries have the necessary resources to understand smallholder dairying in each tropical and socio-economic environment. This unfortunate conclusion can also relate to western influenced agricultural education systems in tropical countries. The centre of these models will be a smallholder farmer rather than a cow.

**Stage of development**

The stage of development of a less developed tropical country is one determinant of the likely future for smallholder dairying. While a superficial comparison of stages of development may suggest an understanding of the expected developments in a country when compared to other slightly more developed countries, this approach can easily lead to unachievable planning goals. For example, the success of smallholder dairying in India owes much of its success to cultural elements which may not be common with other regional countries. Likewise, adaptation of technology to smallholder dairying in tropical countries with a long history and stable dairy industry can support continued improvements in efficiency yet not provide technology which is directly transferable to another situation.

The stage of development of a country is also important in determining the potential for introducing or expanding a smallholder dairy industry, insofar as it determines the existence of a reliable market for milk and milk products. For example, the relatively undeveloped state of the economy of Lao-PDR would suggest that the establishment of a smallholder dairy industry would be unlikely to be viable. That is, unless the industry was associated with a centralised processing facility able to supply fresh milk to a major city market at a price competitive with milk imported, in that case from neighbouring Thailand. The relative economic position of Lao-PDR allows this to occur through lower wage rates and land rentals.

Diversity of production systems also characterises smallholder dairying. Tropical Africa produces around 75 per cent of its milk from cattle usually raised on communally owned pasture areas whereas Asia produces only 30 per cent of its milk from cattle with the major feed source being crop residues. Tropical Latin America produces most of its milk from cattle raised on privately owned pastures. Factoring in such diversity requires a more detailed view within individual countries and socio-cultural and environmental factors including integration within a farming system. As half of the world's human population and three-quarters of Asia's population reside in tropical Asia, the integrated farming system must be a major focus.
and one in which it is impractical to label a farmer as a crop, dairy or other farmer or to solely assign a resource to a specific industry.

The role of market protection

Development of smallholder dairying in the tropics has often been associated with market protection. Such protection has stimulated a range of industries, including dairying, under conditions which would not otherwise be economically viable, in order to improve national food security. However, such industries are often assumed to remain unviable even when protection is gradually removed. Experience suggests that this conclusion can be erroneous when changed market conditions develop during the period of protection, such as that which occurred with changed dietary preference and economic development in Thailand through the 1970s and 1980s. These situations may mirror past stimulation of industries in more developed countries by market protection and progressive shifts in management coupled with production efficiencies in those industries as protection is reduced.

The growth of smallholder dairying in countries where milk prices are maintained at a high level and imports are regulated, as with requirements to blend with locally produced milk in Thailand, stimulated the development of a milk consuming public. In circumstances where milk products are introduced into a rapidly developing economy and associated with improved nutrition and child care among the middle class, milk consumption can rise from virtually zero to substantial levels of demand of low elasticity. In this situation, a premium may continue for fresh milk produced locally, above other milk products which are reconstituted from imported milk powder. Even where such a premium is not sustained, the technical inefficiencies of dairying in the tropics, which may lead to lower levels of production per cow, may be compensated for the lower costs of labour input and product per litre of milk produced.

In the absence of market protection, one might expect the continuation of a viable smallholder dairy industry supplying fresh milk to cities and towns in a manner mimicking the continuing distribution of dairy farms around major cities in more developed countries. Such distribution is largely contrary to economic forecasts of relocation on the basis of costs of production of bulk products even for developed countries. However, the association between density of human population (cities) and milk production only contradicts economic conclusions which are based on false assumptions that dairying is a uniform industry, producing a uniform product, for a uniform market. Such concentrations favour efficient support services thereby challenging a further conclusion that tropical dairying cannot afford to develop the necessary infrastructure to compete with large temperate industries.

The experiences amplified in various chapters of this book suggest that the continued viability of smallholder dairy industries will be based on efficiencies. Thus its future will be defined in terms of the use of cropping and industrial by-products, location, supply of fresh milk, cultural preferences relating to niche markets, labour cost-efficiencies, strategic use of market support mechanisms to assist industry establishment, and the introduction of milk to cultures where it was not previously consumed. While each of these factors can work independently and in concert with others, we expect smallholder dairying to continue to develop in different ways in major regions. It is also expected that subsequent discussions of the subject may well segregate the dairy tropics into; perhaps two regions in Africa; less developed parts of Central and Latin America; North Asia; South Asia, and South East Asia.

Dairying in economic development

The majority of dairying development in less developed countries differs from the circumstances which we see working for development for smallholder dairying in some economies, particularly in Asia. The circled area of Figure 22.1 represents the paradigm of agriculture as the engine of growth. It explains the
The future for smallholder dairying

The circled area of Figure 22.1 represents the paradigm of agriculture as the engine of growth. It explains the relationship between increased agricultural production and economic development in poor countries according to a process which has been demonstrated in many cases. A significant agricultural base producing a surplus provides a basis for industrial development, often initially through agro-industrial products to create greater economic wealth in the form of goods, increased economic activity and employment leading to a general increase in demand.

While the dairy industry can play a part in some countries in creating the initial financial surplus that stimulates such economic development, we note that the development of a dairy industry may be associated with economic development itself. The increased demand for luxury products including milk, particularly as a safe and nutritious food for children, creates a reliable demand for milk supplied primarily as fresh processed product. Such demand for fresh milk in turn provides a reliable market for a dairy industry to develop in such economies. The source of fresh milk is a local dairy industry from an existing agricultural base which, in many rapidly developing economies has not enjoyed the full benefit of economic development. The very split between rural and urban areas which appears to result in development in most cases, means that the urban demand for fresh milk would be more likely to be supplied from smallholder dairy industries which continue to capture the economic efficiencies of smallholder production systems in densely populated agricultural countries. In this way, we see dairy development as a second wave component of economic development. Where assessments for development of dairy industries in less developed countries are undertaken on the assumption that dairying could form part of the initial agriculture as the engine of growth phase (Figure 24.1), the extent of demand for local fresh milk can be grossly underestimated.

**Trends in large and smallholder systems**

Decreasing protection of markets, accelerated by International Monetary Fund intervention in South East Asian economies beginning in 1997-98 may be expected to impact on large holder dairy industries. Nevertheless, large holder dairy investments in the tropics are commonly associated with existing enterprises of diverse products which can operate on the basis of marginal profits as part of existing marketing and distribution systems. Where a continuing market for milk and milk products exists, the higher cost of imported products resulting from South East Asian currency devaluations may provide a competitive advantage to local producers. Notwithstanding such observations, we expect some rationalisation in large holder production facilities, especially those based on intensive tropical dairying technologies adapted from southern United States. This expectation is based on the high comparative cost of producing high quality feed in the tropics which is necessary for the high levels of production expected from such facilities.
Existing processing facilities established under protected environments may increase the proportion of imported blending milk powder and prove attractive for investment by multinational dairy companies and co-operatives. The products of such plants may be distinguished from fresh pasteurised milk by an increasingly discerning middle class, yet capture a large and expanding market through advertising.

The link between small and large holders in many tropical countries has developed into one of the smallholder supplying milk to processing facilities linked with larger producers. In other cases,
smallholders are linked through co-operative milk collection and processing plants. Smallholders tend to continue to increase the number of animals in their herds, from two to six to 12 for example, according to their management capabilities, access to low cost feeds and labour, location with respect to milk collection and markets, land and water availability and the comparative productivity of other agricultural enterprises. Trends among smallholders to shift from hand-milking to simple machine milking may be expected to continue as high quality raw milk is demanded through local processing facilities and by middle-class markets. The adaptation of existing dairy equipment or development of new equipment for this market could lead to a low-cost revolution in milking as labour savings and increased animal health and milk hygiene benefits result. Likewise, improved collection of milk and in particular cooling soon after milking, and associated increases in hygiene above traditional procedures, are increasingly evident. These trends will determine the future nature of smallholder dairying.

The development paths of small and large holder dairy industries in less developed countries may therefore differ from those experienced in the history of dairy development in more developed countries. We do not necessarily expect large dairy enterprises to be the primary form of milk supply in less developed tropical countries nor do we believe that smallholder dairy producers are best understood as production units which will evolve into larger production facilities in the foreseeable future. Rather, we see smallholder dairying connected through co-operatives or as satellites for processing facilities evolving according to market needs, cost structures, and the cultural requirements of specific countries and regions. The short to medium future will, we believe, confirm the importance of such cultural factors as; reticence to kill male calves, reliance on traditional health and nutritional information, seeking of productive activities for labour throughout the year, as distinct from seasonal employment in crop production; affinities in working with animals and in particular bovines and utilising by-products for low to medium output dairy enterprises.

**Technological changes**

New technologies for temperate regions can assist development of tropical dairy industries to the extent that they can be adapted to local cultures and the higher mean temperatures and humidity of the tropics. Technologies developed for production improvement of dairy industries in more developed countries may be categorised in terms of pasture-based such as used in Australia, Ireland and New Zealand, and intensive shed-based production systems such as developed in the United States. It should be noted that the warm and humid areas of the southern United States provide technologies which have been readily adapted to large holder dairying in less developed countries.

Management of animal nutrition, physiological manipulation, reproductive management, health, and milking differ between pasture and housed systems, with some overlap in terms of individual animal efficiency of utilisation of by-products, non-protein nitrogen and selective breeding outcomes. However, large-scale pasture-based systems have limited application to smallholder dairying in the tropics. This is because management systems and selection for high milk yields from pasture do not suit the by-product-based diets, breeding criteria for smallholders, limited land holdings, or current pasture varieties of the tropics. It is of interest to note that concerns are now developing in pasture-based industries, in such countries as Australia, about utilising cattle genetic material, developed in the United States. The superiority of the United States genetic material in that country is not demonstrated under the pasture-based production systems of Australia. The Australian system is based on a lower cost structure, a requirement for animals to harvest most of their own feed and thus be more mobile, and requires cows to be productive for much more than three lactations. The difficulties of technology transfer between these two systems operating in more developed countries with their economic similarities should serve as a warning to the indiscriminate promotion of technologies from developed countries to smallholder dairying systems in the tropics.
Engineering technologies of developed country dairy industries, relating to such processes as milk harvesting, cooling, transportation, factory reception and new product development, may provide technologies directly relevant to large holder industries in less developed countries. However, smallholder-based industries, except where operating as satellites of larger production and processing facilities, may not be best served by large costly processing facilities. There is a need to develop technologies which meet the same objectives of rapid cooling of milk, maintenance of hygiene standards at each stage of handling, and low cost product development. We see technological changes in smallholder dairy industries in the tropics arising from research specific to the needs of smallholders as well as from the adaptation of technologies developed in more developed countries. Insofar as technologies are owned by companies sponsoring their development, one might expect an increase in the number of multinational dairy company investments in, for example, processing facilities which have been established by aid or national governments. On the other hand, smallholder milk products such as those of India do not appear to attract large markets beyond that culture.

**Continuing need for smallholders**

Smallholder producers in the tropics provide a niche for a range of agricultural commodities. This niche is maintained in both market and production terms as a result of historical origins, and cultural preference. In these circumstances, smallholder production can meet the requirements of boutique industries such as the intensive horticultural industries which require high labour inputs to produce near perfect individual pieces of fruit for high price markets. Similarly, effective use of low cost labour as an alternative to organic chemical application can produce a higher priced organically grown product. In the same way, smallholders can provide fresh material, capitalise on local tastes and form a basis for cultural linkages associated with national aspirations for unity, such as through urban linkages to traditional rural industries.

Smallholder dairy industries can produce boutique products for specific markets. The range of dairy products produced in the Indian subcontinent, for which there may be limited global demand, represents one example of boutique products. These range from sweetmeats through to various qualities of ghee. Smallholder dairy producers can also supply fresh milk to their own urban markets, within one day of milking. It is difficult to imagine the widespread supply of fresh milk from abroad, to discerning middle-class markets in the tropics. Educated demand for fresh milk could create a premium for fresh over powdered or blended products. The lower costs of production of smallholders in many tropical countries can compensate for lower levels of output, particularly where high-cost fashion elements of the dairy industry are avoided, such as expensive genetic material developed and sold by more developed countries. Cross-breeding to produce optimal genotypes for smallholder management and nutritional conditions in each local tropical environment can be expected to develop as the viability of smallholder dairying industries in each location is recognised.

There is a need to recognise the continuing place of smallholder dairy producers in the tropics. As discussed in the preceding chapter, orienting research activities to the needs for smallholder tropical dairy industries which are not met by simple importing of technology, is an essential support service for smallholder dairy development for each country and across the tropics. A wider level of understanding is also required among national planners and social analysts to see the benefits that have already accrued from smallholder dairying industries. These may be classified in varying terms which may be grouped as:

- year-round engagement of rural and peri-urban labour
- utilisation of agricultural and other by-products
- integration with cropping systems management
- conversion of by-products to organic manure for application to crops
- provision of nutritious and hygienic food for children
- production of meat from male calves and older cows
- reducing the cost of production of meat for traditional markets in circumstances of rising costs as draught power declines as the primary bovine product
- a basis for rural and peri-urban industrial development through milk factories
- the development of new products for niche exports
- reducing rural to urban population drift
- draught and traction as a dairy industry by-product or adjunct
- landless persons making a reasonable local living from dairying.

This list may not be exhaustive; we hope that it is not. The continuing role for smallholder dairy production in tropical countries should be increasingly recognised as the individual viability of these industries which is demonstrated in the absence of external support. However, it is our contention that the benefits such as those listed above could be more readily realised through appropriate policy, planning and support services.

**International finance and smallholder dairying**

Smallholder dairying in the tropics has not been a popular area for investment by multinational development agencies such as the World Bank, the African Development Bank, the Asian Development Bank and other regional development banks, or even for most bilateral aid agencies. Much of this unpopularity has been related to the high levels of protection afforded dairy industries in both tropical and temperate countries and a consequent assumption that the tropical industries may not survive without protection. Some suggestions that the lack of interest from financing bodies has been related to the export interests of more developed countries may appear unkind. Large multilateral financiers and funders of development activities require large projects and necessarily have focused on industries with which they are familiar. This has worked against the interests of smallholder dairying in tropical countries. Analyses of the viability of the establishment of dairy industries in tropical countries have commonly focused on the introduction dairy industries similar to those of more developed countries, and in particular large holder production enterprises.

Notwithstanding this focus on traditional large holder approaches to dairying, funding agencies have shown flexibility in supporting smallholder-based activities for traditional industries such as cropping. In the cropping industry, investment emphasised the introduction of new technologies, irrigation facilities, and fertiliser purchase and distribution with associated credit. In other circumstances new industries have been introduced, such as, beef production into environments where it was not hitherto known, and into some environments where both economically and in terms of the local biota, it has proven inappropriate. However, smallholder dairying has been largely overlooked except by some European bi-lateral programs. The relative lack of interest in international support for smallholder production of fresh milk for persons in less developed tropical environments provides an opportunity for informed financial, economic, social and technical analyses in each country seeking to improve its smallholder sector.

Arguments that it is economically inefficient to assist the selection of dairy breeds adapted to the environmental, feed and social conditions of a tropical country may appear sound in isolation. The obvious success of India in developing locally adapted breeds points to the benefits of such approaches. Nevertheless, the parallel argument that rice or sugar breeding and production should be limited to the tropics where they have been developed for thousands of years, does not seem to be given the same credence. Such anomalies can be understood in the context of artificial trading, pricing and purchasing arrangements which tend to disadvantage agricultural producers in general and those in the less developed tropics in particular.
Other sources of development finance can also be applied to smallholder dairying. Government programs or even those of benevolent aid organisations tend to impose a model of dairy development drawn from western experience. An exception appears to be Operation Flood in India where a unique understanding of local socio-cultural values allowed collectivisation to the benefit of producers.

However, programs in other countries appear to have taken time to recognise local requirements. In the case of Kenya, a dairy industry existing from colonial times has continued and adapted to local smallholder production systems. The processing sector is faced with a number of changes, and advice as to the appropriate means of managing processing facilities draws heavily on the current experience of more developed countries. There may be a need in such situations for greater acknowledgement of local requirements. Likewise in the production of raw milk, acknowledgement of local socio-economic constraints, required outputs and interpretation of benefits will provide a basis for designing viable projects for financing. We cannot help thinking that, had smallholder dairying in the tropics been seen as a vital indigenous industry and one which did not have an apparently similar raw material output to a major industry in more developed countries, more effort would have been invested in understanding smallholder dairy production and integrated systems in the tropics.

Future development of smallholder dairying in the tropics may well see an understanding that such production systems are unique and do not follow a model which can be drawn from more developed countries. It may also be observed that a variety of objectives can be met from such development in terms of national health, income, population distribution and environmental management. Detailed financial analysis of smallholder dairying in the tropics can yield information which separates viable from unviable smallholder facilities. Embracing economic analyses which acknowledge the contribution of smallholder dairying to cropping, beef and draught as well as to broad social needs implies a viable future for smallholder dairying in many tropical areas.

Characteristics of the future

The future of smallholder dairying in the tropics will be characterised by a number of unique factors. These will be increasingly recognised as characteristics of importance in their own right rather than variations from a desirable norm in dairy production, as may currently be the case. Such characteristics would include:

- production of milk as one of many outputs from integrated farming systems
- reliance on smallholder dairying for the majority of local area milk and milk product supply
- a increased focus for low cost fresh milk production for local towns
- production of boutique milk products, in many cases oriented to local tastes
- utilisation of waste and by-products as principle animal feeds
- adaptation to and utilisation of available local inputs
- development based on self-help, leading in some cases to communally-owned processing facilities
- optimising rather than maximising milk production within a low cost production system
- national agricultural research system investment in smallholder dairying research
- linkages between rural and urban areas through provision of transportable nutritious and, in a preserved form, non-perishable product.

From a distinguished and misunderstood history to the present day, with the application of a number of indigenously developed techniques, and the increasing application of adapted technologies from international research, smallholder dairying in the tropics has established a viable and expanding future. The application of knowledge has been advocated by many, the most eloquently being Mahadevan (1958; 1966) who provided a respectability for a field which in the 2000s should come of age. Nevertheless, in
linking social and natural scientists in support of further development of smallholder dairying in the tropics, a wider understanding by scientists and educators is needed. Scientists must understand the indissoluble link between adoption, new technology development and socio-cultural requirements, and small farmers who have traditionally been neglected and who need education about the inter-relationships between technologies. As with many aspects of less developed country agriculture and indeed integrated farming systems, it is difficult to define an individual as a smallholder dairy farmer alone as this may be simply one of many occupations. The paradigm used in our analysis of such enterprises is in itself a limitation to our ability to further improve complex, efficient, integrated systems. The challenge for development agencies, scientists and educators remains one of further increasing their own knowledge of the variables and relationships within such highly integrated systems and the central role of the smallholder in them.

Suggested reading


EEC (European Economic Community). 1984. Basic Principles- Established at the meeting of ACP-EEC experts on the evaluation of livestock production projects held in Nairobi, Kenya, 1984, EEC.


