TROPICAL DAIRY FARMING

Feeding Management for Small Holder Dairy Farmers in the Humid Tropics

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Foreword

The demand for livestock products will double in the next two decades. Consumption of milk in the developing world is growing at 2.9% per annum from 44 kg per person in 1997 to 62 kg per person in 2020, with the demand in some Asian countries growing by 3.5% per annum.

This demand for milk and dairy products must be met by some means. Some will be met through increased global trade but much, especially the demand for whole fresh milk, will have to be met locally.

There is an unprecedented interest in dairying in the tropical countries of Asia, and to a lesser extent in Africa, led largely by national governments. But, in many of these countries, especially those in South-East Asia, dairy cattle and their products have not been a major part of their cultural heritage. Consequently there is a need for high-quality, well-informed, educational and training materials, if this burgeoning demand is to be met efficiently and effectively in the relatively short time available.

Manuals of the type developed by Dr John Moran in this publication are an essential part of the tool kit that is required for the satisfactory development of good husbandry and efficient production systems for small farmers in Asia.

Dr Moran has drawn on his extensive experience in research for the Australian dairy industry, as well as on his wide personal experience and knowledge of the needs of the South-East Asia dairy industries.

The manual is firmly based on good science. Dr Moran has translated this science into what are currently the best practices for a tropical dairy industry under the conditions that exist throughout large areas of Asia.

John E Vercoe
Chairman, Board of Trustees for the International Livestock Research Institute, Kenya, Africa (1998–2004) and Chairman of the Committee of Board Chairs of the Consultative Group on International Agricultural Research (2002–2003).

Author's note

Dr John Vercoe relaxing with an overseas colleague during one of his ATSE Crawford master classes

Dr John Vercoe passed away suddenly in September 2005. His contributions to tropical cattle production were many and varied over the last 40 years, particularly in international agriculture. John was both my professional and personal friend and along with my colleagues, I will miss him dearly.

About the author

Dr John Moran is an Australian senior research and advisory scientist from Victoria's Department of Primary Industries, located at Kyabram in northern Victoria. He spends half his time advising farmers in southern Australia and half his time working with dairy farmers and advisers in South-East Asia. His specialist fields include dairy production, ruminant nutrition, calf and heifer rearing, forage conservation and whole farm management.

John graduated in 1967 with a Rural Science honours degree from The University of New England at Armidale in New South Wales, followed by a Master's degree in 1969. In 1976, he obtained a Doctorate of Philosophy in beef production from University of London, Wye College in England.

During the 1980s, John lived in Indonesia for three years, working in beef cattle and buffalo research. Since 1999, he has initiated and conducted training programs on small holder dairy production to farmers, advisers and policy makers in Indonesia, Malaysia, Thailand, Vietnam, East Timor and more recently, in China. In so doing, he has built a team of Australian dairy extension specialists in forage production, silage making, nutrition and ration formulation, extension methodology, milking hygiene and reproductive management.

Since 1990 John has worked with an extension team to prepare an extension and training manual on 'Feeding Dairy Cows' for the Victorian dairy industry. He has modified the recommended practices specifically for small holder farmers in the humid tropics based on his South-East Asian experiences and using the same basic principles of nutrition.

John has published more than 200 research papers and advisory articles. He has also written several farmer manuals on dairy and beef cattle nutrition, veal production calf and heifer rearing and on silage production. The first edition of *Calf rearing: A guide to rearing calves in Australia*, published in 1993, sold more than 10 000 copies. The second edition, published in 2002, is now selling widely throughout Australia. He also published a companion book on young stock management, *Heifer rearing: A guide to rearing dairy replacement heifers in Australia*. His book, *Forage conservation: Making quality silage and hay in Australia*, published in 1996, is now a set text for undergraduate study in several Australian universities.

His initial training in a systems approach to livestock science, together with his many years working closely with dairy industries in Australia and South-East Asia stands him in great stead to write this book. This is both a training manual of dairy cow nutrition plus a series of observations on how successful and profitable small holder farmers manage their dairy herds.

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Other books and technical manuals by the author

Books

Calf rearing – A guide to rearing calves in Australia (1993)
Forage conservation – Making quality silage and hay in Australia (1996)
Heifer rearing – A guide to rearing dairy replacement heifers in Australia (with Douglas McLean) (2001)
Calf rearing – A practical guide (2002)

Technical manuals

Maize for fodder – A guide to growing, conserving and feeding irrigated maize in northern Victoria (with Ken Pritchard) (1987)
Growing calves for pink veal – A guide to rearing, feeding and managing calves for pink veal in Australia (1990)
Managing dairy farm costs – Strategies for dairy farmers in irrigated northern Victoria (2002)

Acknowledgments

Throughout the humid tropics, small holder dairy farming was established as part of social welfare and rural development schemes, to provide a regular cash flow for poorly resourced and often landless farmers. Now it is an accepted rural industry and requires a more business-minded approach to farm management. One such method of increasing the cash flow of small holder dairy farmers is to improve the feeding management of their livestock. This is the goal of this technical manual.

This manual is based on one I helped develop for dairy farmers in Victoria, with other government dairy specialists in the Target 10 extension program (Target 10 1999). It has been extensively modified to ensure its relevance to small holder farmers in the humid tropics. I would like to acknowledge my colleagues in the Target 10 Dairy Nutrition team, in particular, Dr Joe Jacobs and Ms Jo Crosby. The body condition scoring system, described in this manual, was developed by Victorian dairy specialists, particularly Dr Richard Stockdale and Ms Chrisanya Robins, whom I also acknowledge.

A team of Target 10 specialists developed training programs for small holder dairy farmers in Indonesia, under the banner of the Indonesian Dairy Feed Management Program. Selected technical information from these and our other Asian training programs is included in this manual and I would like to thank my colleagues:

- Frank Mickan (Victorian Department of Primary Industries, Ellinbank)
- John Miller (Queensland Department of Primary Industries, Murgon)
- Denise Burrell (Faculty of Land and Food Resources, University of Melbourne, Glenormiston Campus)
- Bill Tranter (Tableland Veterinary Service, Malanda, Qld)
  with their considerable expertise in tropical small holder dairy systems, for allowing me to incorporate such information into this manual.

Other colleagues whom I would like to acknowledge for their advice and guidance:

- Prof Bill McClymont (now deceased) from New England University in Armidale, Australia, who first instilled me with enthusiasm about livestock production and feeding while an undergraduate
- Prof Barry Norton from University of Queensland, Australia, with whom I shared many ideas on tropical animal production, as well as quite a few bottles of red wine, over the years
- Dr Devendra from Kuala Lumpur, Malaysia, who keeps trying to help me 'fit into the farmer's shoes' to more fully understand the problems of the small holder dairy farmer in South-East Asia. Or as my Thai colleague Prof Charan Chantalakhana expresses it, seeing the world from the farmer's vantage point.

Finally I would like to acknowledge the generous financial support of The *ATSE* Crawford Fund without whose help the publication of this book would not have been possible.

Dr John Moran
October 2005

Chemical warning

The registration and directions for use of chemicals can change over time. Before using a chemical or following any chemical recommendations, the user should ALWAYS check the uses prescribed on the label of the product to be used. If the product has not been recently produced, users should contact the place of purchase, or their local reseller, to check that the product and its uses are still registered. Users should note that the currently registered label should ALWAYS be used.

Contents

1

Introduction

This chapter:

Presents an outline of the manual and its role in developing training programs for farmers and students. The skills in ration formulation are summarised. Some basic concepts in the nutrition of dairy cows and the terminology encountered throughout the manual are introduced.

The main points in this chapter:

- cows are ruminants
- the mature stomach of the cow has four chambers, the largest of which is the rumen
- cows are well adapted to a forage diet
- cows need water, energy, protein, fibre, vitamins and minerals in their diet.

1.1 The feeding manual

1.1.1 Aims of the manual

Readers of this manual will be able to calculate and provide their dairy cows and young stock with cost-effective feeds that match the targets of their particular farming system. Formulation of diets will be based on using forages first, then supplements. Practical experience will reinforce the understanding of dairy cow nutritive requirements, the benefits and drawbacks of various feed components as well as determining the optimal diet balance. Additional information is provided on growing and conserving quality forages as silage.

Readers will also develop a good understanding of problems encountered when milking cows are fed unbalanced diets, for example the metabolic diseases associated with poor nutrition. Small holders milk cows as a business and must make a profit to remain viable. This manual will teach readers how to calculate profit margins from small holder feeding systems.

The final chapter provides readers with a good understanding of some of the major obstacles to improving feeding management on small holder dairy farms in the humid tropics.

In summary, to develop the skills in supplying and formulating cost-effective rations for dairy stock, farmers need to:

- understand the nutritional requirements of cows and be able to express them in terms of dry matter, energy, protein and fibre
- compare feeds on the basis of their nutritive value
- understand the effect of nutrition on milk production, health and reproduction, and the growth of young dairy stock
- check whether a diet is balanced in terms of energy, protein and fibre
- understand how forages and feed supplements interact, including the factors that affect responses to supplements and how they determine the profitability of supplementary feeding
- calculate milk income less feed costs as a measure of profit
- understand the principles of growing quality forages
- understand the principles of making quality silage.

1.1.2 Outline of the manual

This manual is written for advisers, students and skilled farmers who produce milk from small holder dairy systems in the humid tropics. Much of the basic knowledge needed to understand how cows produce milk is explained in the following chapters.

Although small holders are the major suppliers of milk in the tropics, many larger farms with up to 1000 milking cows, both intensive feedlot and less intensive grazing systems, have been established throughout South-East Asia to satisfy the increasing demand for more fresh milk. Such farmers and their advisers will gain much from this manual. This manual also provides relevant and up-to-date background information to research scientists in many aspects of tropical dairy production, such as forage production and conservation, herd and feeding management and farm management economics. In addition, policy makers and senior managerial staff would benefit from reading selected chapters.

Most tropical countries have proactive programs to increase local supplies of milk, which require an increasingly trained workforce in the dairy industry. Consequently, educators from agricultural schools, universities and technical colleges need to keep abreast of the latest technical developments and applications in dairy farming. This manual also serves this purpose. Some suggestions on how this manual can be used in structured training programs have been presented in Table 1.1 (see Section 1.1.4)

Chapters 2 and 3 describe features of tropical small holder dairy systems and trends in dairy production in South-East Asia. Chapters 4 and 5 provide the elements of ruminant nutrition, highlighting the importance of the rumen as the key organ of digestion. Chapters 6 and 7 quantify requirements for feed nutrients in different demand phases of the cow's lactation cycle.

Feed nutrients are supplied from a wide variety of sources: fresh forages (Chapter 8), conserved forages (Chapter 9), concentrates and forage supplements (Chapter 10), all of which interact when subjected to rumen digestion and metabolism (Chapter 11). The major goal of this manual is to formulate a diet (Chapter 12) for a desired level of animal performance. However, such a production diet may fail to achieve its target and some of the causes are discussed in Chapter 13.

Dairy stock make many demands on nutrients in addition to milk production, such as use in body reserves (Chapter 14), fertility (Chapter 15) and growth prior to calving (Chapter 16). Dairy farming is a business with a variety of economic measures of success. 'Milk income less feed costs' is relatively easy to monitor and provides a useful measure of economic efficiency (Chapter 17).

Milking cows store reserves as body tissue for later use as energy sources and a system for scoring changes in body reserves is described in Chapter 18. This scoring system then provides an objective assessment of how well cows are being fed in relation to their nutrient demands, which fluctuate markedly in the course of a single lactation.

Chapter 19 discusses some of the non-nutritional constraints to performance such as genetic merit, heat stress and effluent management, all major limiting factors for tropical dairying. Attention is also given to problems encountered when importing exotic genotypes into small holder tropical systems.

Much of the research into dairy feeding management over the last 20 years has more relevance for less hostile climates, namely in temperate countries where dairy farming has evolved into more sophisticated production systems. Chapter 20 highlights some of the developments and environmental considerations required for tropical dairy to become and remain more efficient and profitable.

Full publication details of all sources are presented in References and further reading. A glossary of technical terms and abbreviations used in the manual is also provided. Appendixes are included to facilitate sourcing specific information and gaining experience in ration formulation. Appendix 1 presents the Temperature Humidity Index, the universal method of quantifying heat stress in dairy stock. Appendix 2 provides conversion factors to the standard metric system from a wide variety of systems used for describing weights and measures. Appendix 3 presents a currency converter for South-East Asian countries as at February 2005. Tables of nutrient requirements are presented for vitamins and minerals (Appendix 4) and energy, protein and fibre (Appendix 5). Appendix 6 provides four scenarios and the opportunity to calculate nutrient requirements and then formulate the most cost-effective rations.

1.1.3 Sources of information

This manual draws on published information from many sources:

- Chapters 4, 5 and 6 (principles of the feeding management) were developed in Victoria during the late 1990s (Target 10 1999)
- Chapter 8 (growing forages) and Chapter 9 (silage making) were prepared for small holder farmer training programs in Indonesia (Moran 2001a, Mickan 2003)
- Chapter 15 (nutrition and fertility) was adapted from an Australian nationwide extension program 'InCalf' (Morton et al. 2003)
- Chapter 16 (nutrition and young stock) was adapted from my books on the calf and heifer management (Moran and McLean 2001, Moran 2002)

- Chapter 18 (body condition scoring) was developed by a team of Victorian dairy scientists (Robins et al. 2003).

The examples in the manual of practical feeding management were collected from both first-hand experience and published data from many South-East Asian countries.

The author, John Moran, discussing feeding management with a small holder farmer and a dairy adviser in northern Thailand.

1.1.4 Role of the manual in training programs

This manual is multipurpose. It forms the basis of structured training programs in small holder dairying for advisers and educators (for farmer training organisations, agricultural high schools and universities), while also providing background information to researchers and policy makers in tropical dairy industries.

Table 1.1 presents two structured training programs and highlights those chapters written more specifically for dairy researchers and policy makers. Two Dairy Nutrition programs are outlined, first a basic one for farmers and high school students, ‘Feeding dairy cows’, and second, an advanced one for more highly skilled farmers, advisers and university undergraduates, ‘Dairy nutrition and dairy farm production’. It is assumed that participants in the advanced program would be familiar with topics covered in the basic program; if not, they should be introduced initially as an abridged basic course.

The basic ‘Feeding dairy cows’ course introduces participants to:

- chemical constituents of forages and concentrates (Chapter 4)
- principles of ruminant digestion (Chapter 5)
- nutrient requirements of dairy cows and how they vary during the lactation cycle (Chapters 6 and 7)
- nutritive value of tropical dairy feedstuffs (Chapter 10)
- milk responses to supplements (Chapter 11)

- formulating rations for milking cows (Chapter 12)
- body condition scoring (Chapter 18).

The advanced 'Dairy nutrition and dairy farm production' course does not duplicate topics from the basic course and introduces participants to:

- growing and conserving quality forages (Chapters 8 and 9)
- using computers to formulate rations for dairy stock (Chapter 12)
- problems with unbalanced diets (Chapter 13)
- influences of ruminant nutrition on milk synthesis in the udder and on body condition (Chapter 14)
- nutrition and fertility (Chapter 15)
- nutrition and young stock (Chapter 16)
- economics of milk production (Chapter 17)
- overcoming environmental constraints to cow performance (Chapter 19).

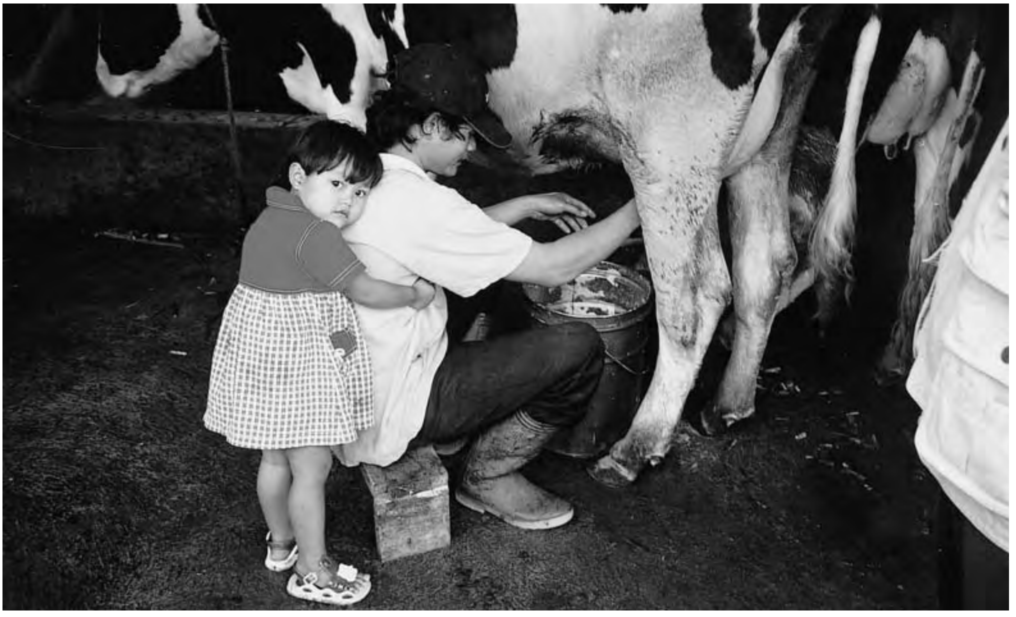
Many of the chapters in the advanced program would also be relevant to tropical dairy researchers and policy makers. Chapters written more specifically for these specialists are:

- tropical dairy systems (Chapter 2)
- small holder dairying (Chapter 3)
- future developments in feeding management in the humid tropics (Chapter 20).

Table 1.1 Suggestions (+) for the selection of chapters from this manual to use in a basic course on 'Feeding dairy cows' (A) and an advanced course on 'Dairy nutrition and dairy farm production' (B) and chapters of special relevance to tropical dairy researchers and policy makers (C)

Chapter	Topic	A	B	C
1	Introduction	+	+	+
2	Tropical dairy systems			+
3	Small holder dairying			+
4	What is in feeds?	+		
5	How the rumen works	+		
6	Nutrient requirements of dairy cows	+		
7	How feed requirements change during lactation	+		
8	Growing quality forages		+	+
9	Making quality silage		+	
10	Supplements for milking cows	+		+
11	Milk responses to supplements	+		+
12	Formulating a diet	+	+	+
13	Problems with unbalanced diets		+	+
14	Diet and milk production		+	+
15	Nutrition and fertility		+	+
16	Nutrition and young stock		+	+
17	Economics of feeding dairy cows		+	+
18	Body condition scoring	+		+
19	Overcoming environmental constraints to cow performance		+	+
20	Future developments in feeding management in the humid tropics			+
Appendices	Units and currency converters, Work sheets	+	+	+

Because of the diversity of dairy farming production systems throughout South-East Asia and the use of different nutritional terms and concepts in different countries, the chapters may contain technical information that is not always most useful, or at the appropriate level for the target audience at the particular training program. It is then up to the course planner to select the information most relevant to the course participants.



Small holder dairy farms are usually family operations (Central Java, Indonesia).

Family small holder farms can easily grow to larger operations when farmers develop their skills in herd and feeding management (West Java, Indonesia).

The chapters are written to be understood by advisers and tertiary students, hence the trainers must ensure that other target audiences can comprehend their course material. For example, Chapter 17 has been excluded from the basic 'Feeding dairy cows' course, even though parts of it are just as relevant to farmers as to advisers and tertiary students. Hence, the course planner should select the most relevant sections to incorporate into the basic course. As the chapters are written as 'stand alone' documents to be accessed via the Internet, there is some repetition, although this has been kept to a minimum.

Two different systems for describing feed energy are used in this manual. Not all South-East Asian countries use the same unit because of their political history and colonial influences,. From my personal experiences, the unit of Metabolisable Energy (ME) is more commonly used by dairy nutritionists in Malaysia and Vietnam, while the unit of Total Digestible Nutrients (TDN) is commonly used in Indonesia, Thailand and the Philippines. Their interconversion is presented in Chapter 4. The Metabolisable Energy system is the preferred one with more widespread usage throughout the world.

1.2 Nutrients for dairy cows

Cows are herbivores and have digestive systems well adapted to forage-based diets. Cows belong to a group of mammals known as ruminants. Ruminants have a complex digestive system, which is characterised by a four-chambered stomach. The largest of these chambers is the rumen.

The digestive system of ruminants enables them to digest plant material in a way that non-ruminant mammals with single stomachs, such as pigs, dogs or humans, can not. The role of the rumen to milking cow is explained in detail in Chapter 5.

The rumen contains large numbers and many types of microorganisms (often referred to as microbes). These microbes feed on plant material eaten by the cow and produce end products that are used by the cow, and also by the microbes for their own multiplication and cell growth.

The microbes themselves are digested further down the digestive tract.

The ultimate purpose of dairy cows is to produce milk, so their diets must allow them to fulfil the functions of lactation, and of reproducing annually.

The nutrients required by dairy cows are water, energy, protein, fibre, vitamins and minerals. These requirements largely determine how we think about the composition of

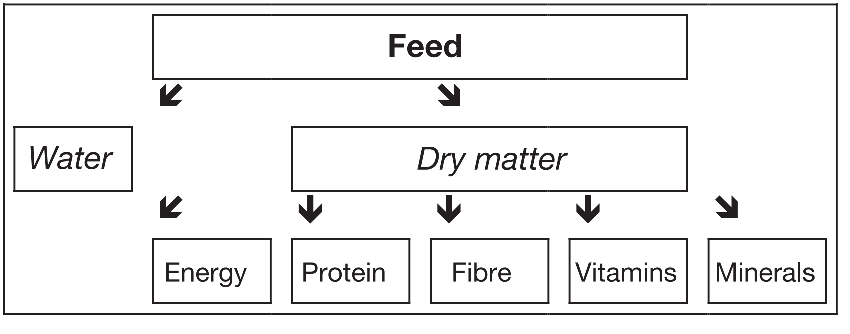


Figure 1.1 The major components of feed. (Source: Target 10 1999)

their feed. Feed contains both water and dry matter. The dry matter component of that diet is the part which contains the necessary energy, protein, fibre, minerals and vitamins. The components of the feed are outlined in Figure 1.1 and are discussed in detail in Chapter 4.

1.2.1 Water

The body of a dairy cow is composed of 70% to 75% water. Milk is about 87% water. Water is not a feed as such because it does not provide specific feed nutrients. However, water is essential to regulate body temperature. As well, water is involved in digestion, nutrient transfer, metabolism and waste removal. Water has structural and functional roles in all cells and all body fluids. An abundant, continuous and clean source of drinking water is vital for dairy cows.

1.2.2 Energy

Dairy cows use energy to function (walk, graze, breathe, grow, lactate, maintain a pregnancy). Energy is the key requirement of dairy cows for milk production. It determines milk yield and milk composition.

1.2.3 Protein

Protein is the material that builds and repairs the body's enzymes, hormones, and is a constituent of all tissues (muscle, skin, organs, foetus). Protein is needed for the body's basic metabolic processes, growth and pregnancy. Protein is also vital for milk production.

Proteins are made up of nitrogen which are bound into various amino acid molecules. Amino acids are the building blocks for the production of protein for milk, tissue growth and the development of the foetus during pregnancy.

Cows require 25 different amino acids for normal metabolic functioning. Fifteen of these can be produced by the cow's own metabolism. The remaining 10 are termed essential amino acids because they must either be supplied in the diet (as dietary protein) or as a product of the digestion of the microbes in the rumen (microbial protein).

Protein is usually measured as crude protein. Nutritionists commonly use terms like rumen degradable and undegradable dietary protein and bypass protein. These terms are explained more fully in Chapter 4.

1.2.4 Fibre

For efficient digestion, the rumen contents must be coarse with an open structure and this is best met by the fibre in the diet. Fibre contains most of the indigestible part of the diet. Cows require a certain amount of fibre for rumen function. It ensures that the cow chews its cud (ruminates) enough and therefore salivates. Saliva buffers the rumen against sudden changes in acidity.

Both the length and the structure of the fibre are important. These determine how much chewing a feed requires. Feeds which need extra chewing increase the flow of saliva.

Fibre in the cow's diet also slows down the flow of material through the rumen and thus gives the microbes more chance to digest the feed. Products of fibre digestion are important for the production of milk fat.

Roadside grass being delivered to small holder farms in Central Java, Indonesia.

Woman holding maize stover in West Java, Indonesia.

1.2.5 Vitamins and minerals

Vitamins are organic compounds that all animals require in very small amounts. At least 15 vitamins are essential for animals. Vitamins are needed for many metabolic processes in the body; for example production of enzymes, bone formation, milk production, reproduction and disease resistance.

Minerals are inorganic elements. They are needed for:

- teeth and bone formation
- enzyme, nerve, cartilage and muscle function or formation
- milk production
- blood coagulation
- energy transfer
- carbohydrate metabolism
- protein production.

2

Tropical dairy systems

This chapter:

Introduces the major features of tropical dairy systems and quantifies the development of dairying in South-East Asia and some of the world's large dairy industries.

The main points in this chapter:

- dairying provides a regular income by converting low value forages and crop residues, and using family labour, into a valued market commodity
- unlike in other tropical and subtropical areas of the world, dairying has only become established recently in South-East Asia
- the emphasis in dairy production is changing from rural development to a business-minded approach to farm management
- by 2020, South-East Asia will supply only 25% of its total milk demand, requiring importations of 9 million MT milk/yr
- for fresh milk to remain competitive with the product reconstituted from imported ingredients, farmers should expect to receive no more than the equivalent of US 30 c/L milk
- small holder farmers in Malaysia and Thailand currently receive in excess of US 30 c/L as a base price, whereas those in Indonesia, the Philippines and Vietnam receive less than this threshold milk return.

Geographers have categorised the tropics into four climate zones, with all months warm or hot, and the zone varying with rainfall and evaporation, as follows:

1. rainy (or humid) tropics, with at most one or two dry months and no winter, with the coolest month above 18°C
2. wet and dry tropics, with a well-developed dry season, with one or two rainy seasons

3 semiarid tropical, with light rainfall and high evaporation
4 hot arid, with negligible rainfall and high evaporation.

The humid tropics include parts of equatorial South America and Africa, the Caribbean and virtually all of South-East Asia. The subcontinent of India is not classified as being in the humid tropics.

2.1 Features of tropical dairy systems

Milk is a cash crop for small holders, converting low value forages and crop residues, and using family labour, into a valued market commodity. The dairy industry occupies a unique position among other sectors of agriculture as milk is produced every day, giving a regular income to farmers. Furthermore, milk production is highly labour intensive, providing a lot of employment. Schelhaas (1999) lists four special features of tropical dairying:

1 Because fresh milk is bulky, and highly perishable it requires high-cost transportation which limits how far it can be profitably sold from its point of production. .
2 The vast majority of producers are small scale, with a weak and vulnerable position in the market place. Consequently in many countries, for its initial establishment, the dairy industry has required considerable market protection, for example as an integral part of the country's rural development policy.
3 Cooperatives play an important part in the dairy industry in developing countries where they are mainly responsible for processing and marketing dairy products. Cooperatives also closely involve producers in many aspects of their industry, such as reproductive and disease management.
4 Milk is invaluable as a source of high quality nutrients, particularly for children. Its high cost necessitates its use for making products with are high value added. Consequently the processing industry is far more important in dairying than in other sectors of agriculture, and such operations must satisfy high technical and quality standards.

Tropical dairy production is a biologically efficient system that converts large quantities of the most abundant feed in the tropics (forages) into the most nutritious of all human foods (milk). Forages are produced as a by-product of crop production or as a specific crop in itself. In return, cattle can improve soil fertility through recycling of nutrients (nitrogen, phosphorus, potassium) and organic matter.

The advantages of integrating dairy production in crop systems offers great potential because, compared to pastoralists and agro-pastoralists, these farmers have more control over feed inputs and are able to capture complementarities in feed resource use and nutrient recycling, which increase overall farm efficiency and reduce vulnerability to market shifts. These crop–livestock systems generally support high rural population densities. Intensification is characterised by increasing farm sizes, upgrading of local cattle and buffalo using more suitable dairy breeds and an increasing reliance on purchased fodders and concentrates. Most tropical dairy systems are small holder (with

Small holder farms usually have limited forage production areas. This farm has a well-managed Guinea grass (*Panicum maximum*) pasture (Binh Duong province, Vietnam).

herd sizes varying from 1 to 20 cows) rather than the larger scale operations commonly found in temperate areas.

2.2 Dairying in the humid tropics, specifically in South-East Asia

The humid tropics of America cover areas of Equatorial Central and South America where livestock production is expanding. However, because of difficult access to markets, dairying is less relevant than beef production in these areas. The opposite is true in the wet and dry tropics where dairy development is largely based on dual-purpose cattle production. Like Central America, milk production in Sub-Saharan Africa is considerably lower than production in Asia, due primarily to low human and cattle populations because of more limited irrigation.

There are continental-specific features of dairying in the tropics. In Sub-Saharan Africa, 75% of the milk comes from cattle, which generally graze communal native pastures. In Asia, only 50% of the milk is produced by cattle (the remainder from buffaloes), which are hand-fed grown forages and crop residues. In Latin America, virtually all the milk comes from cattle grazing privately owned improved pastures. The effects of markets override these features of production systems; with the exception of India and Latin America, market-orientated dairy farms are concentrated near or within urban consumption centres.

Although the principles of improved feeding management discussed in this manual can be profitably incorporated into dairying anywhere in the humid tropics, successful examples in this manual will be mainly those from South-East Asia.

Unlike in other tropical regions, milk from cows and goats is not a traditional component of diets in South-East Asia. Rather, the 'milk' people in South-East Asia consumed came from coconuts, not livestock. The origin of dairying lies in the Middle East, 7000 to 6000 BC, and from there, milk consumption spread to the Mediterranean (and Europe), Indian subcontinent, the savanna regions of West Africa, the highlands of East Africa and to some extent South and Central America. Dairy products were also important to the nomads of Africa and Asia.

Since the 1980s, there has been increasing interest in small holder dairying throughout South-East Asia. Higher population pressures and changes in eating habits have increased the demand for dairy products. Many countries now have school milk programs to encourage young children to drink more milk and hence to improve their health through increased consumption of the energy, protein and minerals (particularly calcium and phosphorus) contained in milk. In future, as these children grow and have families, milk consumption will increase at a faster rate. Consequently, many South-East Asian countries are striving towards self-sufficiency in dairy products, at least in drinking milk.

Throughout South-East Asia, small holder dairying was established as part of social welfare and rural development schemes, to provide a regular cash flow for poorly resourced and often landless farmers. Now it is an accepted rural industry and requires a more business-minded approach to farm management. As feed costs constitute 50% to 60% of the total production costs, one method of increasing the cash flow of small holder dairy farmers is to improve the efficiency of feeding management of their livestock. This is the goal of this manual.

The following tables (sourced from FAO data) presents relevant dairy cow data, up to 2004, on national herd sizes and levels of milk produced in eight countries in South-East Asia (Table 2.1) and for comparative purposes, six other countries with large dairy industries (Table 2.2). The average annual percentage change indicates the relative growth of the various domestic industries, while the milk produced annually per head of population indicates the degree of self-sufficiency (or export potential) for dairy products in each country.

The fastest growing dairy industry in South-East Asia is in Thailand (17% per annum) followed by Indonesia (10%), Vietnam (5%), Myanmar (4%), then Laos (3%) and Malaysia (2%). Myanmar has the largest dairy herd (although tropical dairy specialists often dispute this FAO derived data), while in terms of production, Thailand, Myanmar and Indonesia all produce in excess of 500 kt milk/yr. The dairy industry in Cambodia has hardly changed over the last 30 years whereas in Philippines, it has been in decline since 1985.

The largest dairy industry in the world is in India with 39 million dairy stock and milk production is increasing at over 4% per year. China's industry is also growing rapidly (10% per year), now producing more milk than New Zealand and Australia, the two major dairy export countries in the world. The major dairy industries in the world often have declining national herd sizes but still maintain a 1% to 3% per annum growth, through increases in per cow production. This can be largely attributed to improved feeding management practices, the principles of which are outlined in this manual.

Table 2.1 Changes in the number of dairy stock (000 head), annual milk production (kt or million L/yr) and milk produced annually per capita (or head of human population) (000 L/hd per yr) for eight countries in South-East Asia

Data are for 1970, 1985 and 2004 and the average annual percentage change was calculated over the 34 years (for dairy stock and annual milk produced only). (Source: FAO data)

Country	Parameter	1970	1985	2004	% Change/yr
Cambodia	Stock (000)	115	96	120	0.5
	Milk (kt/yr)	20	16	20	0.4
	Milk/hd (000 L/hd per yr)	2.8	2.0	1.5	–
Indonesia	Stock (000)	59	208	368	6.2
	Milk (kt/yr)	29	191	580	9.7
	Milk/hd (000 L/hd per yr)	0.2	1.1	2.5	–
Laos	Stock (000)	12	20	30	3.1
	Milk (kt/yr)	2	5	6	3.0
	Milk/hd (000 L/hd per yr)	0.9	1.1	1.1	–
Malaysia	Stock (000)	32	37	83	3.4
	Milk (Kt/yr)	17	19	37	2.4
	Milk/hd (000 L/hd per yr)	1.6	1.2	1.6	–
Myanmar	Stock (000)	495	1,127	1,360	2.4
	Milk (kt/yr)	121	575	543	4.0
	Milk/hd (000 L/hd per yr)	4.5	15.5	10.7	–
Philippines	Stock (000)	5	7	5	–1.2
	Milk (Kt/yr)	12	15	12	–0.4
	Milk/hd (000 L/hd per yr)	0.3	0.3	0.1	–
Thailand	Stock (000)	3	26	240	15.8
	Milk (kt/yr)	3	57	825	16.8
	Milk/hd (000 L/hd per yr)	0.1	1.1	9.0	–
Vietnam	Stock (000)	14	42	61	4.5
	Milk (kt/yr)	11	34	78	5.4
	Milk/hd (000 L/hd per yr)	0.3	0.6	1.0	–

Table 2.2 Changes in the number of dairy stock (000 head), annual milk production (Mt or billion L/yr) and milk produced per capita [or head of human population] (000 L/hd per yr) for six large dairy industries

Data are for 1970, 1985 and 2004 and the average annual percentage change over the 34 years (for dairy stock and annual milk produced only). (Source: FAO data)

Country	Parameter	1970	1985	2004	% Change/yr
Australia	Stock (000)	2,673	1,809	2,052	–0.6
	Milk (Mt/yr)	7,756	6,225	10,377	1.4
	Milk/hd (000 L/hd per yr)	618.7	398.0	594.3	–
China	Stock (000)	511	1,680	6,873	8.4
	Milk (Mt/yr)	0.7	2,589	18,850	10.2
	Milk/hd (000 L/hd per yr)	0.8	2.4	6.7	–
India	Stock (000)	18,575	27,700	38,800	2.1
	Milk (Mt/yr)	8,736	17,500	37,800	4.5
	Milk/hd (000 L/hd per yr)	15.7	22.9	34.3	–
New Zealand	Stock (000)	2,320	2,546	3,841	1.7
	Milk (Mt/yr)	5,986	7,884	14,780	2.6
	Milk/hd (000 L/hd/yr)	2,122.8	2,428.1	3,669.1	–
United Kingdom	Stock (000)	3,304	3,312	2,200	–1.4
	Milk (Mt/yr)	12,971	16,022	14,600	0.2
	Milk/hd (000 L/hd/yr)	232.4	281.7	249.1	–
United States	Stock (000)	12,000	10,981	9,084	–0.8
	Milk (Mt/yr)	53,073	64,930	77,565	1.2
	Milk/hd (000 L/hd/yr)	252.6	267.7	266.9	–

Forage maize harvested to feed dairy cows in Guizhou province, China.

2.3 Future demands for milk and milk products in South-East Asia

The demand for milk in South-East Asia is expected to continue increasing, driven by population growth and affluence. Per capita consumption is rising fastest in regions where rapid income growth and urbanisation result in people adding variety to their diets. Because of the relatively high cost of handling perishable final products and taste factors, most of this milk will be produced where it is consumed, aided by increasing imports of feed grains.

Between 1983 and 1997, annual milk consumption per capita in South-East Asia increased from 10 to 12 kg/hd and this is predicted to increase to 19 kg/hd by 2020. This 3% per annum growth will lead to a total milk consumption of 12 million MT/yr by 2020, which Delgardo *et al*. (2003) predicts will require 9 million MT milk/yr net imports to satisfy; this is up from 4.7 million MT milk/yr imported in 1997. Therefore, by 2020, South-East Asia will be producing only 25% of its milk requirements. For these figures, 'milk' is the sum of liquid milk plus milk products in liquid milk equivalent, while the actual consumption of milk as food is less than the total demand for milk because of its use for feeding calves.

This gloomy prediction is magnified by a predicted importation of 8 million MT/yr of cereal grains in 2020 (up from 6.7 million MT/yr in 1997); these cereal grains will be used for all livestock feed, not just dairy stock. Despite this dramatic increase in imports, Delgardo *et al*. (2003) predict that milk prices will actually decrease by 8% between 1997 and 2020. However, it is likely that demands for livestock products will push feed grain prices beyond the reach of many small holder farmers.

2.4 Current farmer returns for fresh local milk in South-East Asia

Unless required to do otherwise for the reasons of good economics, protectionist policies, government support programs and import quotas and tariffs, domestic milk production would need to compete with international milk prices. In the absence of any government support or import restrictions and tariffs (practices which are increasingly being considered by world trade organisations as inappropriate) the benchmark for the value of domestic milk at the factory door is the cost at which it can be produced from imported ingredients at international prices. Sanderson (2004) considers this to be US 28 to 30 c/L, but it could dip as low as US 20 c/L when international prices are their lowest. Therefore in a free market situation, milk processors would not wish to pay more than this for fresh local milk.

What do small holder dairy farmers in South-East Asia currently receive for their product? Table 2.3 compares the current milk returns in local currency units with its equivalent to US 20 and 30 c/L, the range of milk prices suggested by Sanderson (2004). Appendix 3 summarises the currencies of various South-East Asian countries in February 2005. The current milk returns are base prices for fresh milk in each country, prior to the inclusion of premiums or penalties for milk composition and quality. The final column presents current milk returns in US c/L.

Table 2.3 Fresh milk prices in February 2005 in local currency units (from Appendix 3) for various South-East Asian countries and their equivalent for US 20 and 30 cents/L

Country	Currency unit	Current milk price	Equivalent to US 20 c/L	Equivalent to US 30 c/L	Current milk price (US c/L)
Indonesia	Rupiah (Rp)	1720	1840	2763	18.7
Malaysia	Ringgit (MR)	1.23	0.76	1.14	32.3
Philippines	Peso (Ps)	14.0	11.0	16.4	25.6
Thailand	Baht (Bt)	12.0	7.9	11.9	30.3
Vietnam	Dong (VND)	3200	3170	4740	20.2
Australia	Aust cents	28.0	26.0	39.0	21.5

Only in Malaysia and Thailand are milk prices above the US 30 c/L threshold whereas all countries in Table 2.3, except Indonesia, have local fresh milk returning at least US 20 c/L.

The evolution of free trade policies between South-East Asian countries and those from which they import dairy products means that producers may have to expect unit price milk returns to fall even further as removal of trade barriers reduce the price of imported dairy products. Unfortunately since there is little difference in the nutritional or sensory properties of the various milk products made from either fresh or recombined milk, milk processors are unlikely to pay high premiums for fresh raw milk.

Milk prices are usually set by processors with some input from government and after lobbying from producers. Farmers are rarely happy with the milk price and consumers complain about the high cost of dairy products. However, in each country the industry continues to develop, often with the impetus of government school milk programs. There are always some dairy farmers leaving the industry and there may be temporary downturns in milk supplies, such as during the 1997/98 Asian economic crisis. However, as shown in Table 2.1, dairy farming is a growth industry in most South-East Asian countries.

3

Small holder dairying

This chapter

Describes features of small holder dairy systems, their descriptors and benefits of their intensification.

The main points in this chapter:

- small holder dairying flourished in peri-urban areas but shortages of roughages have forced farmers into high concentrate usage
- rural areas provide greater roughage supplies, which generally reduce feed costs thus increasing profitability
- there are many descriptors for small holder dairy systems – these can be categorised as physical, farm family/financial and institutional
- intensification provides many benefits to farmers but requires certain prerequisites to be sustainable.

3.1 Features of small holder dairy systems

Milk is a cash crop for small holders, converting low value forages and crop residues, and using family labour, into a valued market commodity. Small holder dairy systems are common throughout the developing countries of Asia, Sub-Saharan Africa and Latin America. The main difference between systems is whether they are pasture-based, as in most parts of Latin America and Sub-Saharan Africa, or if dairy production is a part of crop–animal systems, which is more common in Asia.

Devendra (2001a) categorises small holder dairy production systems into three systems:

1 traditional, usually with ad hoc marketing arrangements, such as many peri-urban farms
2 cooperative, formed from natural aggregation and concentration of farms

3 intensive, where herd sizes become larger – one recent example is colony farming in Indonesia, where large sheds house up to 200 cows, but the small herds are still owned by individual farmers, who may share the labour and rewards of communal forage production and herd management.

One important feature of all small holder dairy systems is their rapid expansion throughout the humid tropics, driven essentially by the urban demand, and the opportunities to generate income. The ownership of between 1 and 20 animals, and a small area with crops or pasture, leads to a situation in which milk production becomes the major component of farm income. Such models are common in peri-urban areas, where good markets and production services are often found. Unlike beef cattle on small holder farms, dairy cows have rarely been used as draught animals, thus allowing all their feeding management to be directed towards producing milk and calves.

Dairy farmers can produce milk from six different types of ruminant animals, large (cattle and buffalo plus camels in Africa and yaks in Asia) and small (goats and sheep). Small ruminants are rarely milked in the humid tropics. Of the two buffalo ecotypes, river buffalo are the traditional dairy stock, with swamp buffalo rarely milked. Most milk in the humid tropics is derived from cattle, with some buffalo milk produced in Myanmar, Vietnam, Philippines and Thailand. The large buffalo milk producing countries, India, Pakistan, China and Nepal, are not located in the humid tropics. This manual will then concentrate entirely on milk production from dairy cattle.

Feeding and nutrition have been highlighted repeatedly as major constraints to animal production systems globally. The significance of improved nutrition is particularly important since feed costs make up 50% to 60% of total costs of milk production (see Chapter 17). In small holder systems, inadequate land and size of operation are further production constraints.

Small holder dairy farm in Chonburi province, Thailand.

Small holder dairy farm in Central Luzon, Philippines.

3.1.1 Peri-urban versus rural-based systems

Many countries have peri-urban areas where small holder dairying has flourished on the outskirts of large towns and cities. Such areas have access to good supplies of feed, such as:

- green fodder, native and cultivated grasses and legume forages
- crop residues such as rice straw and maize stover
- agro-industrial by-products and non-conventional feeds
- concentrates.

Too frequently the limited amounts of good quality roughages combined with an intensive approach to peri-urban areas have forced dairy farmers to rely heavily on concentrates. This has increased feed competition with the needs of other livestock species. In general, the feed requirements of livestock in the humid tropics of South-East Asia are in excess of supply (Devendra 2001a). Better use can be made of local resources. Improving low quality roughage through better feed management, and preserving high quality green fodder by improved storage methods are the most promising strategies for reducing feed costs and the dependence on other feed stuffs. The greater availability of forages, whether they be sourced as by-products from crops or from areas of specialist livestock fodder production, is encouraging a rural-based small holder dairy industry. The relative profitability of peri-urban and rural-based dairy farms is discussed in Chapter 17.

There are major constraints to dairy production, however, whether it be peri-urban or rural, such as:

- choice of species or breeds
- availability of animals
- feed resources and improved feeding systems
- improved breeding, reproduction and animal health care

- management of animal manure
- organised marketing and marketing outlets.

3.1.2 Gender roles on small holder dairies

As the cows are generally located in close proximity to the home, dairying offers more opportunities for females to become closely involved in the daily management than with other farming pursuits. This is important in the village life of South-East Asia, where women have traditionally been the home makers and family rearers.

The cultural and religious bonds that limit the contribution of females to managing the family budget have frequently been loosened in many small holder dairying communities. In West Java, for instance, Innes (1997) has documented gender roles in small holder farm activities in four dairy cooperatives. She reported that women were responsible for over 40% of the management and spent 52% of their working hours on farm-related jobs. Men were largely responsible for sourcing forages, often from large distances particularly during the dry season. However, women frequently milked the cows, transported the milk to the collection centres, cleaned the shed and looked after the young stock. This has important implications in technology transfer, which has traditionally been the male's domain. Since milking hygiene is largely the responsibility of women, milk quality is definitely an area where extension should be directed towards them. Workshops on feeding management and young stock are two others areas where more attention should be given to attracting women participants.

3.2 Descriptors of small holder dairy systems

There are nearly as many types of small holder dairy systems as there are farms, because most farms are unique in some way. There are many descriptors of individual farms and these could be categorised into three types: physical, farm family/financial and institutional.

Physical descriptors of individual farms include:

- **magnitude of scale –** farm size, herd size, annual milk production, proportion of farm income from milk sales, off farm family income
- **stock type –** multipurpose (milk, meat, draught), upgraded local stock, milking buffaloes, dairy genotypes, imported or locally sourced
- **sheds and other equipment –** flexibility for future expansion, 'colony farm', forage chopper, milking machines
- **home grown forages –** forage type, forage area, multipurpose crops, fertiliser usage (manure, inorganic, by-products), harvest interval, forage conservation policy, tree legumes, communal forage area
- **purchased feeds –** forages, crop by-products, agro-industrial by-products, formulated concentrates, feed costs as proportion of total farm costs
- **externally sourced forages –** beside road sides, around rice paddies, government forest, plantation estates
- **dry season feeding strategies –** accept feed shortages, conserved quality forages, cereal straws, regularly sourcing forages from distant locations

- **farm production characteristics –** bull calves reared for beef, use AI or herd bull, hand or machine milk harvesting, heifer replacement policy.

Farm family/financial descriptors of individual farms include:

- **land ownership –** purchased, leased, essentially landless
- **stock ownership –** direct purchase, finance loans and government stock credit schemes with low interest and/or repayment with female calves
- **labour –** years of dairy experience, family members or occasional employed labour, gender role on farm activities and decision making
- **family income –** off farm income, other farm enterprises, proportion of farm income from dairy enterprise, proportion of dairy income from sales of milk, manure, calves and cull cows
- **farm management skills –** reproductive management, risk aversion, motivation to improve skills, concerns about environmental sustainability, preferred methods of seeking new information
- **milk price –** payment for volume only or milk composition and quality, farmer input into price, entire enterprise under cooperative or government control.

Institutional descriptors of individual farms include:

- **milk marketing –** cooperative (fresh milk, processed milk), milk processor or bulk purchaser, local consumers (raw milk, processed in farm kitchen), transport raw milk to collection point
- **farmer support system –** supported by dairy cooperative, milk processor and/or government, discussion group networks
- **monitoring milk quality –** measures of milk quality, price signals (premium/penalties), vaccination records to ensure withholding periods are followed, individual or farmer group feedback, incentives/motivation to improve hygiene
- **price control –** formal or informal contracts for farm inputs as well as milk sales
- **cooperative agreement –** volume fee or set farmer fee for membership
- **cooperative services –** veterinary services (foot trimming, routine vaccinations), artificial insemination services, subsidised semen, formulated concentrates, bulk purchase of feeds, bulk supply of forages (maize green chop or silage), provision of financial loans, supermarket for farm and family supplies, regional animal health services (eg mastitis, brucellosis)
- **government support –** effluent and odour legislation, infrastructure of extension services
- **additional support –** contract calf or heifer rearing, local discussion groups (technical, administrative), cooperative farmer training programs, availability of credit from lending organisations, access to farm management and profitability advice, degree of institutional support flowing through to individual farmers
- **sustainability of farming –** improved soil fertility, reduced soil erosion, changes in environmental pollution, production per unit of water
- **regional economic parameters –** liquidity of farming families, changes in stock prices at local level, changes in price of purchased feeds (forages, by-products, formulated concentrates)

- **other performance indicators of farming households –** number of children going to school, improvement in human health, stability of dairy cooperatives, growth of regional and national dairy markets, relative price of imported dairy products.

3.3 Benefits of intensifying small holder dairying

Small holder farms generally yield low outputs of milk per animal. However, on a cost-benefit basis, the use of by-products or other waste as feed, and multiple outputs such as draught and meat production, the continued efficiency of small holder systems can outweigh the apparent efficiencies of dairying monocultures. Application of current technologies will allow increases in the production and efficiency of milk production by better understanding the nutrient requirements for milk production, in addition to those for growth and draught purposes.

The term 'intensification' requires clarification. In general terms, intensification is understood to be increases in efficiency for a unit of a given resource. For advisers and researchers of crop–livestock or pasture-based livestock production, the term is often interpreted as increasing productivity per unit of land, usually associated with an increase in stocking rate.

There are many benefits in improved productivity and profitability of small holder dairy farmers. In addition to higher levels of milk production (hence gross returns) per cow and/or per farm, Falvey (1999) lists the following:

- 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 into 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 meat production for traditional markets as draught power declines as the primary bovine product
- a basis for rural and peri-rural 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 people making a reasonable local living from dairying.

In spite of several decades of dairy farming in developing countries, the productivity of small holder dairying has remained relatively low due to a lack of appropriate dairy research. Furthermore, small farmers because of their socioeconomic and agro-economic conditions being greatly different to those in developed countries, cannot readily adopt the science and technology available in developed countries. Even the most appropriate technology is rarely transferred to small holders due to a lack of effective services. There must be institutional support to facilitate dairy industry growth through mechanisms such as providers of farmer credit, farmer training centres, well-equipped milk collection centres, processing and marketing facilities, farmer cooperative or groups and appropriate research and extension infrastructures and methodologies. School milk programs have been successful in developing small holder dairying through establishing new markets by promoting milk drinking to improve health among children, particularly in rural areas. It is then essential that any production technology being transferred is relevant to the needs of small holders as well as being feasible, given their local support networks of dairy cooperatives, advisers (government and agribusiness), creditors and milk handling and processing infrastructures.

For intensification to be sustainable, there must then be:

- adequate infrastructure and marketing opportunities
- access to reliable markets for increased milk production
- promotion of dairy development through government policy
- availability of credit for purchasing of livestock and planting pastures
- available productive and adapted forage species
- ready access to information
- a farm management system which ensure adequate feed throughout the year
- management of animal wastes
- disease control measures
- adequate hygiene for milk collection.

4

What is in feeds?

This chapter

Explains the important constituents of feed for dairy cows and how ration ingredients are sampled and analysed for chemical analyses.

The main points in this chapter:

- dry matter (DM) is the feed remaining after all the water has been removed – all other components of feed are expressed as a proportion of dry matter
- digestibility (expressed in %) is the proportion of a feed which is not excreted as manure, and is used to describe feed quality
- Metabolisable Energy (ME) is the energy available from feed used by the cow for maintenance, activity, milk production, pregnancy and weight gain
- Total Digestible Nutrients (TDN) is sometimes used to describe energy available in feeds
- Crude Protein (CP) includes both true protein (made up of amino acids) and Non-Protein Nitrogen (NPN) which rumen microbes can convert into protein
- Neutral Detergent Fibre (NDF) is the preferred measure of dietary fibre – it includes indigestible and digestible fibre
- Crude Fibre (CF) is used to describe dietary fibre in certain countries, because of its inclusion in TDN calculations
- it is important to obtain a representative sample of any feed to be analysed, ensuring minimum deterioration between sampling and its arrival at the testing laboratory.

4.1 Dry matter

Dry matter (DM) is that portion of the feed remaining after all the water has been removed. The dry matter part of a feed contains the nutrients: energy, protein, fibre, vitamins and minerals. Dry matter is measured by weighing samples of feed before and after they have been dried at 100ºC for 24 hours. The proportion of dry matter in a feed is usually expressed as a percentage of the wet feed. Different feeds contain different proportions of dry matter and water (Figure 4.1, Table 4.1).

The chemical composition of tropical feeds is sometimes expressed in terms of percentage of fresh feed, in which case, that value should be divided by the DM content, expressed as a proportion (not a percentage). For example, if the protein content of fresh grass is 2% (of its fresh weight) and its DM content is 20%, then its protein content is 2 ÷ 0.2 or 10% on a DM basis.

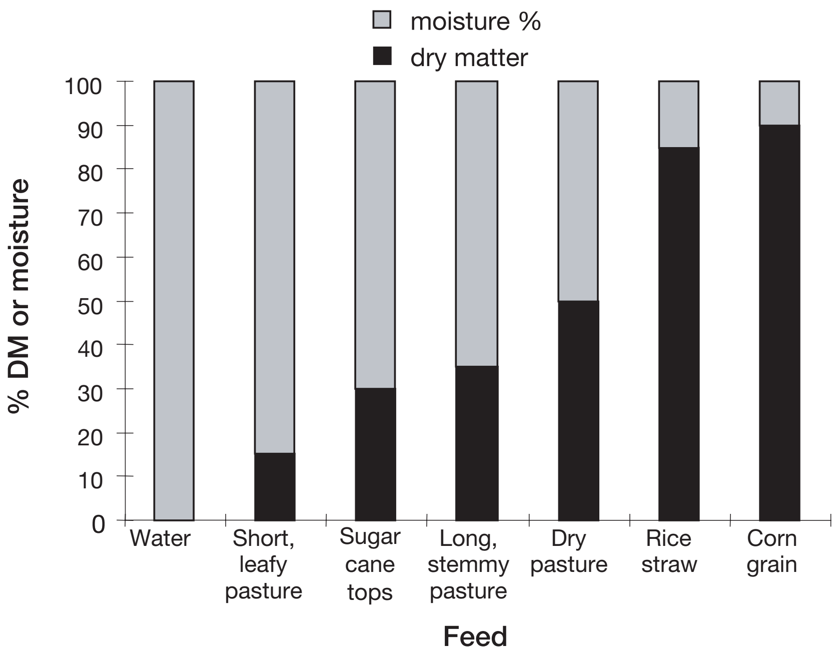


Figure 4.1 Dry matter and moisture content of some typical tropical feeds.

Table 4.1 The approximate dry matter and moisture content of some typical tropical feeds

Dry matter (%)	Moisture (%)	Feed
0	100	Water
10	90	Banana stems
20	80	Young pasture
30	70	Corn silage
40	60	Mature pasture
50	50	
60	40	
70	30	
80	20	Urea treated rice straw
90	10	Corn grain
100	0	

4.2 Energy

The energy in feed is a measure of that feed's ability to help the cow function and be productive. All feeds have a gross energy value (Figure 4.2). Some of the gross energy is lost in the faeces. The energy that is absorbed by the cow is termed digestible energy. From the digestible energy, further energy losses occur in the production of urine, as well as digestive heat and gas. All the remaining energy is known as Metabolisable Energy (ME).

Megajoules are used to measure energy content, although the term megacalories is still sometimes used. The higher the value in megajoules, the better the quality of the feed. In certain South-East Asian countries, energy is often described in terms of Total Digestible Nutrients (TDN).

The Metabolisable Energy (ME) is the energy available for use by the cow: it is the energy used for maintenance of body systems, activity, milk production, pregnancy and weight gain.

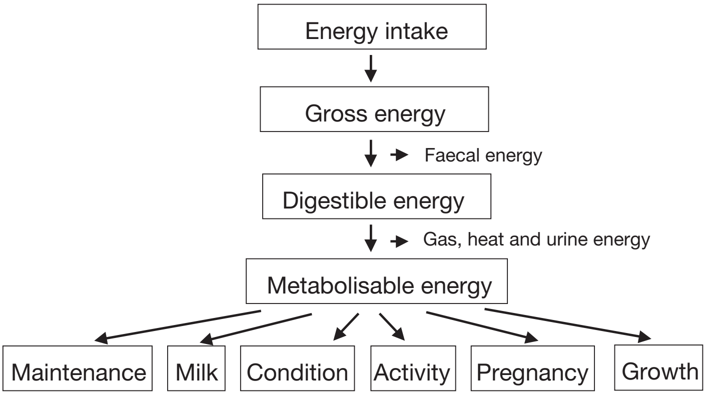


Figure 4.2 The flow and partitioning of dietary energy through the cow.

4.2.1 How energy is measured

Three measures of energy are digestibility, Metabolisable Energy and Total Digestible Nutrients.

Digestibility

Digestibility relates to the portion of food which is not excreted in the faeces and so is available for use by the cow. Digestibility is not a direct measure of energy, but it does indicate overall feed quality. The greater the digestibility, the greater the benefit of that food to the cow because the cows are able to digest and use more of the feed. Thus, the higher the digestibility, the higher the Metabolisable Energy.

Digestibility is commonly measured as a percentage. A grass with a digestibility of 50%, for example, means that only half of the feed eaten will actually be of use to the animal. The other half will be excreted in the faeces. The digestibility of various feed constituents can be determined, with Organic Matter Digestibility (OMD) sometimes being used to describe feed quality. OMD is a measurement of the percentage of digestible organic matter per total dry weight.

Metabolisable Energy

Cows cannot use all the energy released by digestion. Some of the energy is belched out of the rumen as methane and carbon dioxide, some is passed out in the urine while some is lost as heat created during rumen fermentation (Figure 4.2). The energy in a feed that a cow can use for its metabolic activities (ie maintenance, activity, pregnancy, milk production, gain in body condition) is called Metabolisable Energy. The Metabolisable Energy content of a feed can be calculated directly from its digestibility.

The Metabolisable Energy content of a feed (also called its energy density) is measured as megajoules of Metabolisable Energy per kilogram of dry matter (MJ ME/kg DM), although some United States texts express energy in megacalories per kilogram of dry matter (Mcal ME/kg DM). Intake of Metabolisable Energy is expressed in megajoules per day (MJ/d).

The higher the energy content of a feed, the more energy is available to the animal. If a feed contains 10 MJ/kg DM, then each kilogram of dry matter of that feed contains 10 megajoules of Metabolisable Energy available for use by the cow. A feed containing 12 MJ/kg DM then has a higher energy content than a feed containing 10 MJ/kg DM.

For most roughage feeds, it is possible to convert digestibility to Metabolisable Energy as follows:

$$\text{ME} = 0.17\ \text{DDM\%} - 2.0$$

For corn silage, because of its higher organic matter content, the conversion equation should be:

$$\text{ME} = 0.16\ \text{DDM\%} - 0.8$$

where DDM% is dry matter digestibility (%) and ME is Metabolisable Energy (MJ/kg DM).

Total Digestible Nutrients

An alternative method to describe feed energy is Total Digestible Nutrients (TDN). This is an older energy system but it is used in the United States and some countries whose nutritionists studied in the United States. It is not used formally in Australia and other countries whose nutritionists studied in England. It is a less accurate measurement of energy than Metabolisable Energy because it does not take into account energy losses via methane (from rumen digestion) and urine. The two systems are interchangeable through the use of conversion equations (National Research Council 2000). Total Digestible Nutrients content is expressed as a percentage, with Total Digestible Nutrients intake expressed in kg/d.

The amount of Total Digestible Nutrients is calculated from the proportions of digestible crude protein, crude fibre, nitrogen free extract and ether extract (or crude fat). Nitrogen free extract is the difference between the total dry matter and the sum of ash, crude protein, crude fibre and ether extract. As it is difficult to measure the digestibility of all these feed nutrients, Total Digestible Nutrients must be calculated from prediction equations of the total content of each of these feed nutrients. This requires separate equations for various feed types. Some generalised equations are available, and the following provides a reasonable prediction of Total Digestible Nutrients from the concentration of individual feed nutrients:

$$TDN = 5.31 + 0.412\ CP\% + 0.249\ CF\% + 1.444\ EE\% + 0.937\ NFE\% \qquad \textbf{Equation 1}$$

where CP% is percentage crude protein, CF% is percentage crude fibre, EE% is percentage ether extract, and NFE% is percentage nitrogen free extract.

The following equations allow a conversion from Metabolisable Energy to Total Digestible Nutrients, and from Total Digestible Nutrients to Metabolisable Energy:

$$TDN = 5.4\ ME + 10.2$$

$$ME = 0.185\ TDN - 1.89.$$

Throughout this manual, references to the energy density of feeds will be given in these two measures, as Metabolisable Energy (as MJ/kg DM) and Total Digestible Nutrients (as %). References to the energy requirements or intakes of cows will also be presented in these two measures, either as Metabolisable Energy (MJ/day) or Total Digestible Nutrients (kg/d).

To facilitate the calculation of energy values of forages and concentrates, I have developed an EXCEL spreadsheet that calculates Total Digestible Nutrients and Metabolisable Energy contents of feeds directly from their chemical analyses using Equation 1 above. This program, 'the TDN workbook', is freely available from the author, Dr John Moran, at john.moran@dpi.vic.gov.au.

Table 4.2 presents the relationship between digestibility, Metabolisable Energy and Total Digestible Nutrients, while Table 4.3 presents the interconversion between the two.

Table 4.2 Relationship between dry matter digestibility, Metabolisable Energy and Total Digestible Nutrients

Dry matter digestibility (%)	Metabolisable Energy (MJ/kg DM)	Total Digestible Nutrients (%)
40	4.8	36
45	5.6	41
50	6.5	45
55	7.3	50
60	8.2	54
65	9.0	59
70	9.9	64
75	10.7	68
80	11.6	73
1 unit	0.17 unit	0.9 unit

Table 4.3 Interconversion between Metabolisable Energy and Total Digestible Nutrients

Metabolisable Energy (MJ/kg DM)	Total Digestible Nutrients (%)	Total Digestible Nutrients (%)	Metabolisable Energy (MJ/kg DM)
4	32	30	3.7
5	37	40	5.5
6	43	45	6.4
7	48	50	7.4
8	53	55	8.3
9	59	60	9.2
10	64	65	10.1
11	70	70	11.1
12	75	80	12.9
1 unit	5.4 units	1 unit	0.185 unit

4.2.2 Types of energy

Energy can come from various parts of the feed. Carbohydrates, fats and oils, and even protein can provide energy.

Carbohydrates

Plant tissue dry matter is about 75% carbohydrates. Carbohydrates are the main source of energy for livestock. Sugar molecules of various types are the building blocks of carbohydrates. The sugars are chemically bound together in different numbers and in a variety of ways to form the three types of carbohydrate: soluble, storage and structural.

Soluble carbohydrates are the simple or individual sugars found in the cells of growing plants. They are digested and used almost instantly by the microbes in the rumen. Soluble carbohydrates are digested 100 times faster than storage carbohydrates. Soluble carbohydrates are found more in leaf than in stem.

Storage carbohydrates are made up of sugar subunits which are chemically bound together and are found inside plant cells. Starch is an example of a storage carbohydrate. Storage carbohydrates are digested about five times faster than structural carbohydrates. Storage carbohydrates are found in grains, leaf and stem and in the bulbous roots of fodder crops.

Structural carbohydrates are fibrous components of plant cell walls. They provide the structural support that plants need to grow upright. Pectin, hemicellulose, and cellulose are all structural carbohydrates. Large amounts of structural carbohydrate are found in mature pasture and straw. Lignin and silica are often associated with structural carbohydrates in plants. They give structural support to plants but are indigestible and are not actually carbohydrates. They can bind to the structural carbohydrates and make them less digestible.

Fats and oils

Only 2% to 3% of forages are fat or oil. Fats and oils include vegetable oils, tallow (animal fat) and processed fats. No more than 5% of a cow's total intake of dietary dry matter should be fats. Fats can decrease the palatability of the diet and coat the fibre, interfering with its digestion by rumen microbes.

Protein

The rumen microbes can use a surplus of protein in the rumen for energy. This is, however, an inefficient use of protein.

4.2.3 Energy and milk production

Diets for three cows, producing 13 L, 17 L or 20 L is shown in Table 4.4. The second column shows the amount of energy each cow needs to eat each day to produce that amount of milk.

The dairy farmer has two feeds available to give to the cows:

- mature pasture, with an energy density of 8 MJ/kg DM of Metabolisable Energy and
- green, leafy grass, with an energy density of 10 MJ/kg DM of Metabolisable Energy.

To produce more milk, a cow must eat more dry matter. If lower quality (ie lower energy density) feed is provided (eg 8 MJ/kg DM), the cow must eat more of it.

Therefore, to produce 20 L of milk on the mature pasture, a cow must eat 20 kg DM/d – a virtually impossible task.

Table 4.4 Cows fed diets of different energy density and producing at three levels of milk production: amounts of dry matter required daily

Milk yield (L/d)	Daily energy requirement (MJ ME)	Daily required intake (kg DM)	
		8 MJ/kg DM	10 MJ/kg DM
13	125	15.6	12.5
17	146	18.2	14.6
20	161	20.1	16.1

4.3 Protein

4.3.1 Types of protein

Crude protein

Dietary protein is commonly termed 'crude protein'. This can be misleading, because crude protein percentage (CP%) is not measured directly but is calculated from the amount of nitrogen (N%) in a feed:

$$CP\% = N\% \times 6.25$$

Some of the nitrogen is true protein, whereas there are other sources of nitrogen, called Non-Protein Nitrogen (NPN). The microbes in the rumen are able to convert this non-protein nitrogen into true protein if sufficient energy is available to them. Because of this, both sources of nitrogen can be used as protein source by the cow. The components of crude protein are shown in Figure 4.3.

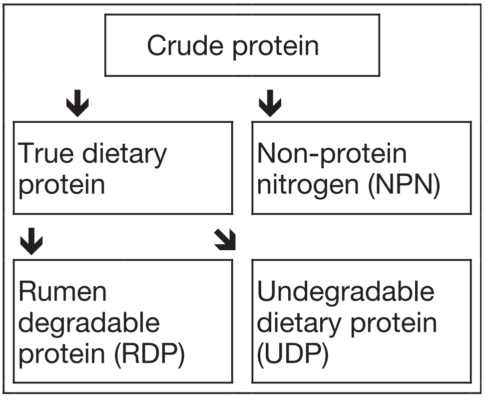


Figure 4.3 The components of crude protein.

Non-protein nitrogen

Non-Protein Nitrogen (NPN) is not actually protein, it is simple nitrogen. Rumen microbes use energy to convert non-protein nitrogen to microbial protein. In the forage-fed cows, however, the rumen microbes use non-protein nitrogen with only 80% efficiency (compared to true protein), which reduces the overall value of crude protein. Urea is a source of non-protein nitrogen.

Rumen degradable protein

Rumen Degradable Protein (RDP) is any protein in the diet that is broken down (digested) and used by the microbes in the rumen. If enough energy is available in the rumen, some rumen degradable protein will be used to produce microbial protein.

Undegradable dietary protein

Undegradable Dietary Protein (UDP) is any protein in the diet that is not digested in the rumen. It is digested 'as eaten', further along the gut. That is why undegradable dietary protein is sometimes called 'bypass protein'.

The proportion of the protein in the diet which bypasses rumen digestion (ie becomes undegradable dietary protein) varies with several factors: first, how well the protein is protected from the rumen digestion; and second, feed intake.

Feeds can be protected from the rumen digestion through treatment with heat or chemicals. However, if the treatment is too severe, the protein can become 'overprotected' in that it passes through the entire gut and out the other end without being digested.

The undegradable dietary protein content of feeds then depends on how much is eaten in total, and how quickly the feed flows through the rumen. Greater intake and faster flow-through mean that more of the dietary protein becomes undegradable dietary protein because it simply 'escapes' through the rumen before microbial breakdown can occur.

4.3.2 Measuring rumen degradable protein and undegradable protein

Nutritionists may want to know how much of the crude protein in the feed is rumen degradable protein and how much is undegradable dietary protein. This analysis is called protein degradability. The degradability of protein in the diet depends on many factors including dry matter intake, how long feed stays in the rumen, the degree of processing, the total protein intake and the supply of dietary energy to the rumen microbes. Therefore, the proportions measured in a laboratory test for rumen degradable protein and undegradable dietary protein may not necessarily be the same as when that feed is eaten by a cow.

Nevertheless, a system describing the degradability of protein has been developed to help assess the undegradable dietary protein supply in feeds. This classification is shown in Table 4.5 and will be used in Chapter 10. A feed with lower rumen degradable protein, hence higher undegradable dietary protein, has more milk production potential.

Table 4.5 Categories used to assess ability of feeds to supply undegradable dietary protein (Source: Target 10, 1999)

Category	Undegradable dietary protein (UDP)	Rumen degradable protein (RDP)
High	More than 69%	less than 31%
Good	69–50%	31–50%
Moderate	49–30%	51–70%
Poor	29–10%	71–90%

4.4 Fibre

For efficient digestion, the rumen contents must be coarse, with an open structure, and this is best met by the fibre in the diet. Fibre makes up the cell wall, or structural material, in a plant and is made of hemicellulose, cellulose and lignin. Some of the fibre is digestible, some is not.

4.4.1 Types of fibre

There are three methods of describing the fibre in feeds.

Neutral Detergent Fibre

Neutral Detergent Fibre (NDF) is a measure of all the fibre (digestible plus indigestible parts) and indicates how bulky the feed is. Some of it is digested, and some is excreted. A high Neutral Detergent Fibre might mean lower intake because of the bulk. Conversely, lower Neutral Detergent Fibre values lead to higher intakes (see Table 12.1).

Acid Detergent Fibre

Acid Detergent Fibre (ADF) is the poorly-digested and indigestible parts of the fibre (ie the cellulose and lignin). If the Acid Detergent Fibre is low, the feed must be very digestible (ie of high quality).

Crude fibre

Crude Fibre (CF), although sometimes used to indicate fibre content, is now considered an unacceptable measure because it does not take into account the digestible fibre which is nutritionally useful to the animal, both a source of energy in the diet and as a substrate for some of the rumen bacteria. However, it is commonly analysed because it is required in the calculation of Total Digestible Nutrients.

4.4.2 Measuring fibre

Different approaches to measuring fibre are shown in Figure 4.4. Sometimes the fibre in the diet is expressed as kilograms of dry matter (kg DM), but more often, fibre is expressed as percentage of dry matter (% DM). For example, if a feed contains 25% NDF, one-quarter of its dry matter weight is fibre.

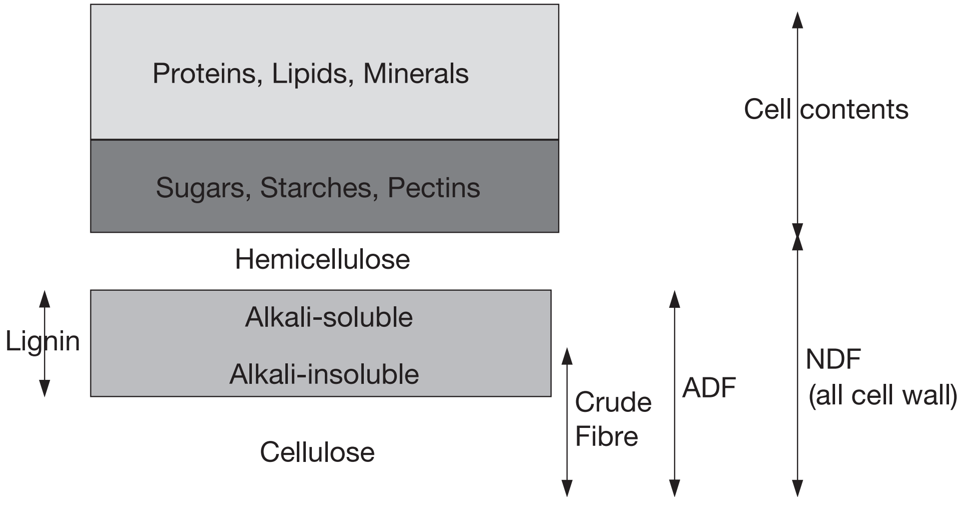


Figure 4.4 Forage analysis showing the difference in definitions of Crude Fibre, Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF).

4.5 Vitamins and minerals

4.5.1 Vitamins

Vitamins are organic compounds that all animals require in very small amounts. At least 15 vitamins are essential for animals. Vitamins are needed for many metabolic processes in the body (eg for production of enzymes, bone formation, milk production, reproduction, disease resistance).

The vitamin needs of most ruminants are met under normal conditions by natural feeds, microbial activity in the rumen, and tissue synthesis. Vitamins A, D and E are usually present in adequate amounts in quality forage. Members of the B-vitamin group and Vitamins K and C are synthesised in the tissues and rumen.

Vitamins are either water soluble or fat soluble. The water-soluble vitamins of importance to cows are the B group of vitamins and Vitamin C. The important fat-soluble vitamins are A, D, E and K.

Vitamins are normally expressed in international units (IU). Vitamin deficiencies are rare in normal forage feeding situations.

4.5.2 Minerals

About 21 minerals are essential for animal health and growth. However, many of these can become toxic if the animal eats too much of them. Mineral deficiencies are less likely if forages constitute the major part of the diet.

High-producing herds fed diets high in cereal grain or maize silage may require added minerals.

The mineral content of feed is expressed in units of weight: gram (g) or milligram (mg). Further details on the important vitamins and minerals required by dairy cows are provided in Appendix 4.

4.6 Essential nutrients and sources summary

Essential nutrients, their sources in feed and the units by which they are measured are summarised in Table 4.6.

Table 4.6 Sources and units of measurement of nutrients essential in the diet of dairy cows

Nutrient	Source in feed	Unit of measurement
Energy	Carbohydrates Fats and oils Protein	Megajoules of Metabolisable Energy (MJ ME/kg DM) kg of Total Digestible Nutrients (kg TDN/kg DM)
Protein	Rumen degradable protein (RDP) Undegradable dietary protein (UDP) Non-protein nitrogen (NPN)	Crude protein percentage (CP%) % Degradability of protein
Fibre	Structural carbohydrates	% Neutral Detergent Fibre (% NDF) % Acid Detergent Fibre (% ADF) % Crude Fibre (% CF)
Vitamins	Present in feeds Some synthesised by microbes in the rumen	International units (IU)
Minerals	Present in feeds	Grams (g) or milligrams (mg)

4.7 Sampling feeds for chemical analyses

It is important to obtain a representative sample of any feed to be chemically analysed. This is easy for homogenous feeds, such as cereal grains or finely ground by-products, but very difficult for heterogenous feeds such as freshly harvested Napier grass (*Pennisetum purpureum*) or pasture hay.

Moderate quality Napier grass harvested for dairy cows in West Java, Indonesia.

Fresh forages will deteriorate very quickly, so they should be taken to the laboratory as soon as possible after sampling. Storing them in a freezer will preserve their quality for weeks, as will storage in a refrigerator for a few days. Silage should be restored in airtight plastic bags, with all the air squeezed out prior to sealing. Wet by-products should also be kept air tight and chilled. Dried forages and concentrates will not deteriorate if kept dry and cool.

With silages, it is essential that the sample arrives at the laboratory in a similar state as in the silage stack. If left to dry out before leaving the farm, volatile compounds will be lost and these contain both energy and protein.

Ensure that any instructions from the laboratory are closely followed, detailing the date of sampling, full description of the feed to be tested and method of storage prior to transport to the laboratory.

4.7.1 Fresh forages

Walk through the paddock selecting whole plants or randomly sample a stack of freshly harvested grass, taking entire plants. Select say six plants and chop each one up into short lengths (no more than 5 cm long). If cows routinely leave a lot of grass stems, the bottom stems of the grass can be left out of the sample. It is much more difficult obtaining a representative sample of tall erect grasses (eg Napier grass) than prostrate creeping grasses (eg Ruzi grass, *Brachiaria ruziziensis*).

With fresh shrubs and trees, it is important to sample only the part of the forage that the animals consume, such as the leaves and thin stems.

Poor quality banana leaves harvested for dairy cows in West Java, Indonesia.

Poor quality alang alang grass (*Imperatica cylindrica*) harvested for dairy cows in Central Java, Indonesia.

4.7.2 Dry feeds

Select a handful from at least six locations or different bags that make up a complete batch. Combine the samples into one and mix thoroughly to obtain a final quantity not exceeding 500 g.
With concentrates mixed on the farm, it is better to sample all the ingredients individually rather than a single mixed batch.

4.7.3 Silages and wet by-products

Ideally, silages should be sampled by forcing a metal corer into the stack when newly opened. These corers can be made of steel tubing 30 to 45 cm long, an internal diameter of 20 to 30 mm, with one end sharpened to allow it to be forced into the silage stack. Corers can be driven into forage stacks by using a hand drill or electric drill.

Alternatively since such devices are rarely available, silages can be sampled by taking many (at least 10) small handfuls over a few days and bulking them into a plastic bag which is kept sealed and frozen (or at least chilled) between samplings. This is easier with wet by-products such as cassava waste or brewer's grain because these are more homogenous than the forages made into silage.

4.7.4 Hays and straws

Hay and dried grasses are the most difficult to sample because the leaves are very brittle and will easily separate from the stems. Corers are really the only way to ensure a representative sample of bales of hay, by sampling 10 to 20 small bales.

Straws are easier because the leaves and grains have usually been removed prior to harvest. All forages should be cut to short lengths of no more than 5 cm.

Cassava trunks do not provide many nutrients when fed as a dry season roughage source to milking cows (Central Java, Indonesia).

5

How the rumen works

This chapter:

Explains the role of the rumen, which allows breakdown and digestion of the forages consumed by cows.

The main points in this chapter:

- cows rely on rumen microbes to convert feed components into useable sources of energy and protein
- speed of digestion depends on the size of feed particles, digestibility of feed and level of intake
- growth and multiplication of microbes depends on rumen pH and the supply of energy and protein
- rumen microbes ferment carbohydrates to make Volatile Fatty Acids (VFA) and gases
- Volatile Fatty Acids are the major source of energy for the cow and the amount of each Volatile Fatty Acid produced depends on the diet
- microbes break down rumen degradable protein and non-protein nitrogen into amino acids and ammonia to build more microbial protein
- microbes are flushed out of the rumen and digested and absorbed in the abomasum and small intestine – this 'microbial protein' supplies most of the cow's protein
- dietary protein not broken down in the rumen can also be digested and absorbed in the abomasum and small intestine
- most fats are digested in the small intestine.

Unlike monogastrics, cattle have rumens, which allows them to make use of feeds that would otherwise be wasted if consumed, through the microorganisms (or microbes) living in the rumen. Therefore, the approach to feeding dairy cows is 'look after these microbes and they will look after the cow'.

5.1 The digestive system

Three steps are involved in cows obtaining nutrients from their diet:

- ingestion: taking food into the body
- digestion: food is mechanically and chemically broken down
- absorption: nutrients pass from the digestive system into the cow's blood stream.

The digestive system of dairy cows is well adapted to a forage-based diet. As ruminants, cows have one true stomach (the abomasum) and three other compartments (the rumen, the reticulum, the omasum) which each have specific roles in the breakdown of the feed consumed (Figure 5.1).

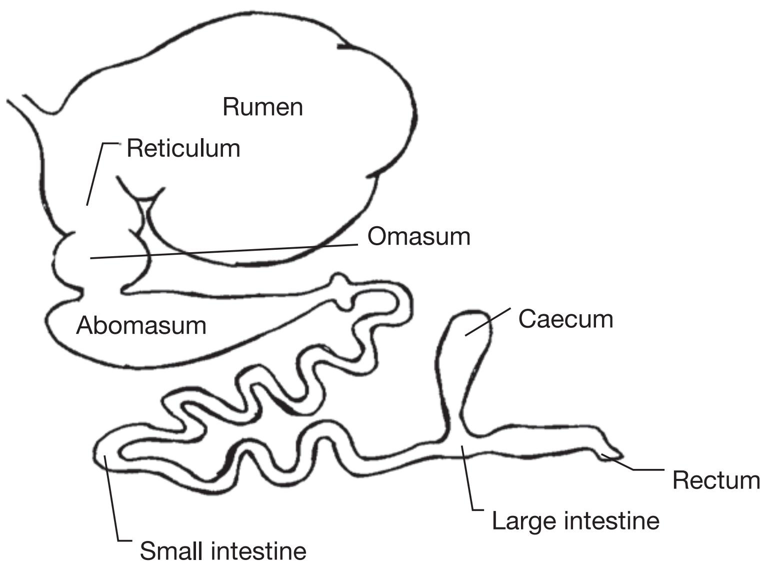


Figure 5.1 Digestive system of the dairy cow.

5.1.1 Rumen and the reticulum

Once food has been ingested, it is briefly chewed and mixed with saliva, swallowed and then moved down the oesophagus into the rumen. The rumen is adapted for the digestion of fibre. It is the largest compartment of the adult ruminant stomach. The rumen is sometimes described as a 'fermentation vat'. Its internal surface is covered with tiny projections, papillae, which increase the surface area of the rumen and allow better absorption of digested nutrients.

The reticulum is separated from the rumen by a ridge of tissue. Its lining has a raised honeycomb-like pattern, also covered with small papillae. The rumen and reticulum together have a capacity of 50 to 120 L of food and fluid. The temperature inside the rumen remains stable at around 39°C (range 38–42°C) which is suitable for the growth of a range of microbes.

The microbes break down feed through the process of fermentation. Under normal conditions, the pH of the contents of the rumen and reticulum is maintained in the range of 6 to 7. It may be lower in grain-fed cows. The stable pH range is maintained by continual removal, via the rumen wall, of acidic end products of microbial fermentation, and by the addition of bicarbonate from the saliva.

Saliva
Saliva has several roles: it makes chewing and swallowing easier, but primarily it contains sodium (Na) and potassium (K) salts that act as buffering agents against acidity.

A cow can produce 150 L or more of saliva daily. The volume of saliva secreted depends on the time spent eating and ruminating.

Chewing and rumination
Before food reaches the rumen its breakdown has already started by the mechanical action of chewing. Enzymes produced by the microbes in the rumen initiate chemical breakdown. The walls of the rumen and reticulum move continuously, churning and mixing the ingested feed with the rumen fluid and microbes. The contractions of the rumen and reticulum help the flow of finer food particles into the next chamber, the omasum.

Rumination, or chewing the cud, is the process whereby newly eaten feed is returned to the mouth for further chewing. This extra chewing breaks the feed down into smaller pieces, thereby increasing the surface area of food particles, making it more accessible to the rumen's chemicals. As a result, the rate of microbial digestion in the rumen is increased.

The time spent ruminating (chewing the cud) depends on the fibre content of the feed. The more fibre in the feed, the longer the ruminating time required, therefore the less feed that can be eaten overall, and the less milk will be produced.

Some nutrients are absorbed across the rumen wall. Absorption involves the movement of individual feed components through the wall of the digestive tract into the blood stream where they are transported to the liver.

There is a constant flow of digesta through the digestive tract. Because food larger than 1 mm cannot leave the rumen until its length is reduced, the rumen is the major regulator of feed intake.

Passage of food through the rumen
The passing of material through the rumen affects the extent of digestion. The general rate of passage depends on density, particle size, ease of digestion and level of feeding. Some foods pass through the digestive system fairly quickly, but very indigestible food may be excreted over a long period.

5.1.2 Microbes of the rumen and the reticulum

The microbes in the rumen include bacteria, protozoa and fungi. These microbes feed on forages ingested by the cow, and, by fermentation, produce end products that are utilised by the cow as well as by the microbes themselves for their own reproduction and cell growth.

Bacteria and protozoa are the most important microbes. Billions of bacteria and protozoa are found in the rumen. They digest about 70% to 80% of the digestible dry matter in the rumen. Different species of bacteria and protozoa perform different functions. Some digest starch and sugar while others digest cellulose.

The numbers and proportions of each type of microbe depend on the animal's diet. Maintaining a healthy mixture of different microbes is essential for keeping the rumen functioning efficiently.

The major end products of microbial fermentation are:

- Volatile fatty acids, the products of fermentation and the cow's main energy source.
- Ammonia, used to manufacture microbial protein. Bacteria are 60% protein, making them the major source of protein for the cow as they leave the rumen and are digested in the abomasum and small intestine.
- Gases, sources of wasted energy, as they are belched out regularly.

Dietary upsets, such as feeding too much grain too quickly, can cause a rapid change in the microbial population. This changes fermentation patterns and interferes with fibre digestion. The level of grain fed should be adjusted gradually so that the populations of rumen microbes can change accordingly.

5.1.3 Rate of digestion

The speed of digestion of feeds depends on the quality and composition of the feed. It is affected by the number and type of microbes, the pH in the rumen, the nutrients that limit the growth of the microbes and the removal of microbes from the rumen. Energy and protein are the major nutrients that limit microbial growth and, therefore, rumen fermentation.

The microbial population needs energy and protein for growth and multiplication. If either of these nutrients is in short supply, microbial growth is retarded, and so is the rate of digestion (the digestibility) of feed.

5.1.4 Omasum

The omasum lies between the reticulum and abomasum. The material entering the omasum is made up of 90% to 95% water. The primary function of the omasum is to remove some of this water and to further grind and break down feed. Large plate-like folds, known as laminae, extend from the walls of the omasum. These folds are attached in the same way as pages are bound to the spine of a book. The laminae are covered in papillae which direct the flow of food particles towards the next chamber, the abomasum.

5.1.5 Abomasum

The abomasum connects the omasum to the small intestine. Acid digestion, rather than microbial fermentation, takes place in the abomasum, much the same as in the human stomach.

The lining of the abomasum is folded into ridges, which produce gastric juices containing hydrochloric acid and enzymes (pepsins). The pH of these gastric juices varies from 1 to 1.3 making the abomasum very acid, with a pH of about 2.

The acidity in the abomasum kills the rumen microbes. The pepsins carry out the initial digestion of microbial and dietary protein in the abomasum.

5.1.6 Small intestine

From the abomasum the digested food moves to the small intestine. Secretions of bile, with a very high pH, change the digesta from acidic to alkaline, allowing digestion of different feed nutrients. There, enzymes continue the digestion of feeds and microbes. Most nutrient absorption occurs in the small intestine.

5.1.7 Large intestine

The large intestine, mainly the caecum and colon, is the site of secondary fermentation, particularly of fibre. About 10% to 15% of the energy used by the cow is absorbed from the large intestine. Absorption of water, minerals and ammonia also occurs here. The components of feed not digested in the large intestine pass through to the rectum and are then expelled as faeces.

5.2 Carbohydrate digestion in the rumen

When food is eaten by the cow, the nutrients are initially in the form of carbohydrates, proteins and fats (or lipids). These are digested to products, which can be used directly by the cow or by the microbes in the rumen.

Plant tissue dry matter is about 75% carbohydrate. Microbial fermentation breaks carbohydrates down into simple sugars. The microbes use these sugars as an energy source for their own growth and make end products, which are used by the cow.

The end products of microbial fermentation of carbohydrates include:

- volatile fatty acids, mainly acetate, propionate and butyrate
- gases, such as carbon dioxide and methane.

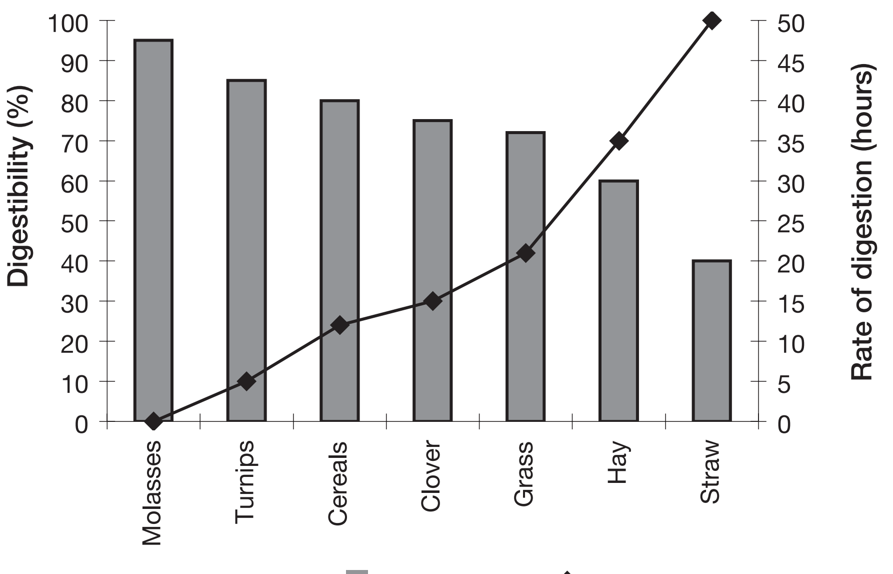


Figure 5.2 Relationship between digestibility ■ and rate of digestion ◆. (Source: Ørskov 1987)

Rumen microbes ferment all carbohydrates, but the soluble and storage forms are fermented more quickly than the structural forms. Sugars and starches are broken down easily and quickly. By comparison, cell-wall material is digested slowly.

As plants mature their cell walls become lignified. The lignin reduces the availability and utilisation of structural carbohydrates. In other words, as plants mature, their digestibility declines because the components of their cell walls become less accessible and harder to digest.

Soluble carbohydrates are digested 100 times faster by the microbes in the rumen than are storage carbohydrates, while storage carbohydrates are digested about five times faster than the structural carbohydrates.

Figure 5.2 shows the relationship between digestibility and rate of digestion for some common feeds.

5.2.1 Structural carbohydrates

Bacteria, which digest structural carbohydrates (cellulose and hemicellulose), produce a large proportion of acetic acid, important in the production of milk fat. These bacteria are sensitive to fats and acidity in the rumen. If feeds contain too much fat or if the rumen becomes too acidic through feeding rapidly digestible carbohydrates, these bacteria can be completely eliminated or their growth rate slowed down. Reduction or elimination of these bacteria not only reduces the digestibility of the feed, it may also reduce the cow's intake of feed.

Once structural carbohydrates have passed through the rumen, there is little likelihood that they will be broken down further.

5.2.2 Storage carbohydrates

The bacteria that digest starchy feeds (eg cereal grains or potatoes) are different from the cellulose-digesting bacteria. They are insensitive to acidity and produce mainly propionic acid. Starches are rapidly fermented, and the lactic and propionic acid they produce causes acidity to increase. The acidity caused by excess starch-digesting bacteria can suppress the bacteria which digest cellulose and so reduce the milk fat level.

5.2.3 Soluble sugars

The bacteria that ferment feeds high in soluble sugars (eg molasses, sugar cane, good quality grass) are similar to those that ferment starch. Sugary feeds generally cause fewer problems with increased acidity in the rumen than starchy feeds (see Section 5.2.4 below). However, sugary feeds need to be introduced to the cow's diet slowly.

5.2.4 The products of carbohydrate digestion

Volatile Fatty Acids

The most important end products of carbohydrate breakdown in the rumen are Volatile Fatty Acids (VFAs). These acids are important because:

- they are the major source (70%) of energy for the ruminant
- the proportions in which they are produced determine fat and protein content of milk.

The three major Volatile Fatty Acids produced are acetate (or acetic acid), propionate (or propionic acid) and butyrate (or butyric acid). The ratio of the various Volatile Fatty Acids produced depends on the type of feed being digested.

Volatile Fatty Acids are absorbed through the walls of the rumen and are then transported in the blood to the liver. In the liver they are converted to other sources of energy. From the liver, the energy produced is used to perform various functions (ie milk production, maintenance of body systems, pregnancy, growth) (Figure 5.3).

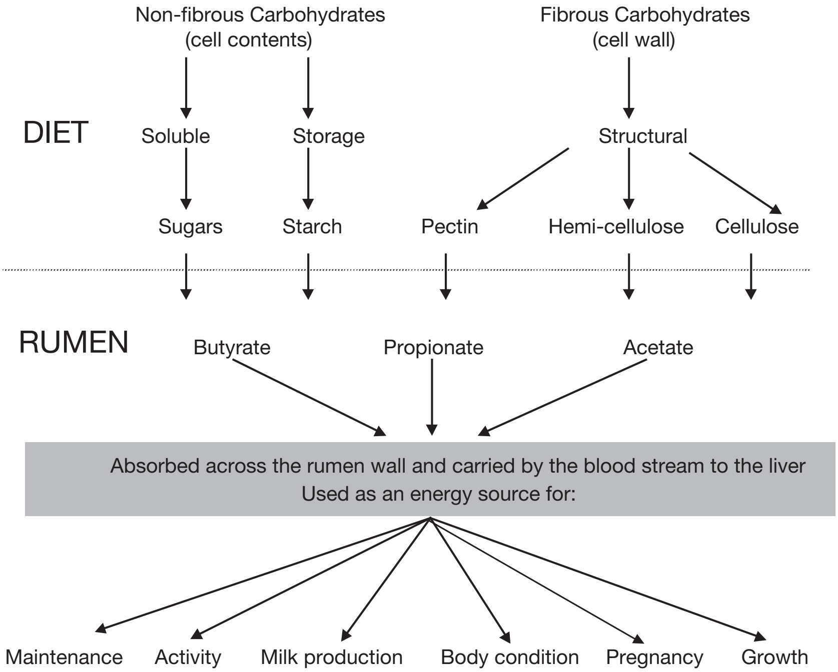


Figure 5.3 Digestion of carbohydrates, and production and absorption of volatile fatty acids in the dairy cow. (Source: Target 10 1999)

Acetate

Acetate is an end product from the fermentation of fibre. Highly fibrous, low energy feeds such as pasture hay lead to microbial populations which produce high ratios of acetate to propionate.

Acetate is necessary for the production of milk fat. If acetate production is low, which occurs in diets high in grain (or low in fibre), milk fat production may be depressed.

Propionate

Propionate is an end-product of fermentation of starch and sugars. Most of the energy needed for live weight gain and for the mammary system to produce lactose is obtained from propionate.

Feeds high in rapidly fermentable carbohydrates such as cereal grains lead to populations of bacteria which produce relatively more propionate and butyrate than acetate. Propionate is considered a more efficient energy source because fermentations, which favour the production of propionate, produce less wasted methane and carbon dioxide.

If too little propionate is produced, which can occur during the feeding of high-fibre diets, the synthesis of milk lactose and overall milk yield is reduced. To compensate for the energy deficit caused by insufficient propionate, body fat is mobilised and the cow loses body condition.

Butyrate

Butyrate is metabolised in the liver into ketone bodies. Ketone bodies are used as a source of energy for fatty acid synthesis, skeletal muscles and other body tissues. Ketone bodies are also produced from the mobilisation of body fat. If a cow is underfed in early lactation and loses body condition to compensate for a lack of dietary energy, the ketone bodies are utilised as an alternative energy source.

Further details of the roles of VFAs in dairy cow diets are discussed in Chapter 14.

Gas

Carbon dioxide and methane are produced during the fermentation of carbohydrates. They are either removed through the rumen wall or lost by eructation (belching). Some carbon dioxide is used by the intestinal microbes and by the cow to maintain bicarbonate levels in saliva. Methane cannot be used by the cow's body systems as a source of energy.

5.3 Digestion of protein

Protein, when digested, is broken down into peptides, which are short chains of amino acids. Further digestion of peptides yields individual amino acids and eventually ammonia. The protein used by the cow may be from the feed she eats or from the microbes washed from the rumen. The amount of each depends on the extent to which dietary protein is degraded in the rumen and on the growth and outflow of microbes from the rumen (Figure 5.4).

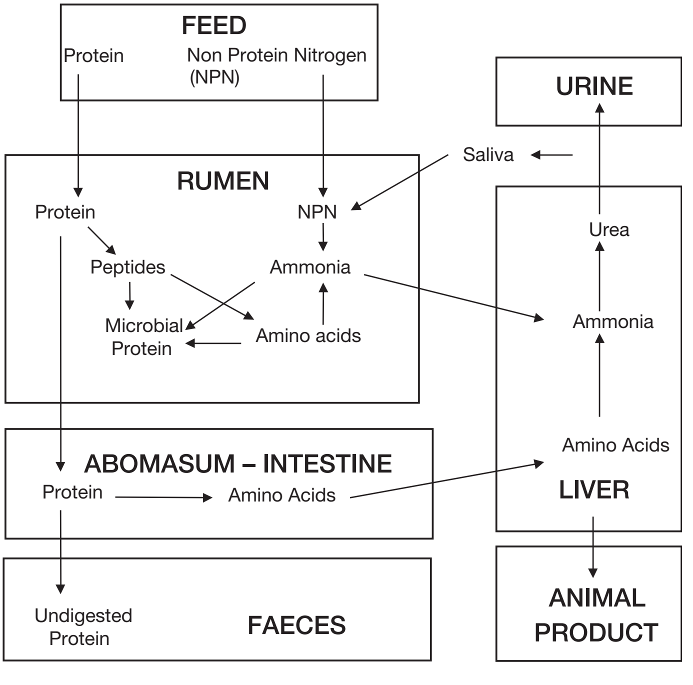


Figure 5.4 Breakdown and partitioning of dietary and microbial protein sources in the dairy cow. (Source: Target 10 1999)

5.3.1 Microbial protein

Rumen microbes are the major source of protein in the cow's diet. They break down Rumen Degradable Protein (RDP) to amino acids, then ammonia. Ammonia is a major source of nitrogen for microbial growth. The microbes also convert non-protein nitrogen to ammonia.

Microbes are continually 'flushed' from the rumen, through the omasum to the abomasum, where they are killed and digested by the cow. The amino acids produced from the digested microbial protein are absorbed through the small intestine. The amount of microbial protein flowing to the intestines depends on the availability of energy and ammonia in the cow's diet.

If energy is limited, microbes become less efficient at using ammonia. Instead of being converted to microbial protein, the ammonia is absorbed across the rumen wall and into the bloodstream. In the liver, ammonia is then converted to urea. Most of this urea is excreted in the urine although some is recycled back into the rumen as non-protein nitrogen in the saliva.

When energy is in excess relative to protein, the rate of microbial protein synthesis declines. Total protein supply to the cow is reduced and milk yield and milk protein yield decreases. Excess energy is converted to body condition rather than milk. Generally, though, good quality forage-based diets are relatively high in protein.

5.3.2 Dietary protein

The dietary protein that is directly available to the cow is Undegradable Dietary Protein (UDP) and any rumen degradable protein which has escaped microbial digestion. This protein is digested in the abomasum and small intestine. Undegradable protein and 'escape RDP' provide a greater diversity of amino acids than does protein broken down in the rumen, which is restricted to those proteins, and their component amino acids, found in microbes.

5.4 Digestion of fats

Fats are a source of energy for the cow. Fats are either partially degraded in the rumen or assume a bypass or protected form. When microbial fermentation of fats occurs in the rumen, some vitamins required by the cow are also produced. Fats are present in most of the more common dairy feeds in relatively small amounts.

No more than 5% of the total diet dry matter (or about 500 g/d) should consist of fats. Beyond this level, fat will coat the dietary fibre in the digestive tract, interfering with fibre digestion and decreasing the palatability of the diet.

Protected fats, which escape microbial digestion in the rumen, can be used to overcome the digestive upsets caused by high levels of rumen-degradable fat. The protected fats are readily digested and absorbed across the wall of the small intestine. Interest in feeding protected fats to lactating dairy cows is growing. However, they are very expensive and only relevant to high producing herds (30 L/d or more), and therefore are not practically relevant to small holder farmers.

Fats such as those from oilseeds (eg whole cottonseed) are useful because they increase the energy density of the diet, particularly in early lactation, thus helping to reduce live weight loss.

6

Nutrient requirements of dairy cows

This chapter:

Explains the specific nutritional needs of cows and how to calculate their energy requirements for major metabolic activities – maintenance, activity, milk production, pregnancy and change in body condition.

The main points in this chapter:

- energy requirements change according to cow size, activity, stage of pregnancy, weight gain or loss and level of milk production
- protein requirements vary with stage of lactation
- microbial protein can sustain production of up to 12 L/d. Up to this level of production, all protein in the diet can be Rumen Degradable Protein (RDP). Beyond this, Undegradable Dietary Protein (UDP) requirements rise as production increases
- good quality forage contains both rumen degradable protein and undegradable protein – cows fed good quality forage and producing up to 30 L/d are unlikely to need supplementary undegradable dietary protein
- the absolute minimum amount of fibre is 30% Neutral Detergent Fibre (NDF) or 17% Crude Fibre (CF).

Dairy cows have an enormous potential to produce animal carbohydrate, protein and fat, but they also have very high nutrient requirements to achieve this potential. For example, over 12 months the quantity of protein produced by Friesian cows in milk can vary from 0 to 1 kg/d. This is equivalent to beef steers just maintaining weight through to gaining weight at 8 kg/d, or more than four times faster than in commercial herds. To achieve such performance levels, dairy cows must be able to consume up to 4% of their live weight as dry matter each and every day.

6.1 Water

Lactating dairy cows in the tropics require 60 to 70 L of water per day for maintenance, plus an extra 4 to 5 L for each litre of milk produced.

Water requirements rise with air temperature. An increase of 4°C will increase water requirements by 6 to 7 L/d. High yielding milking cows can drink 150 to 200 L water/d during the hot season.

Other factors influencing water intakes include dry matter intake, diet composition, humidity, wind speed, water quality (sodium and sulphate levels), and the temperature and pH of the drinking water.

6.2 Energy

Cows need energy for maintenance, activity, pregnancy, milk production and for gaining body condition.

6.2.1 Maintenance

Energy is used for maintaining the cow's normal metabolism. This includes breathing and maintaining body temperature. Physical activities such as walking and eating add to the maintenance requirement, as does environmental temperature and physiological state (ie pregnancy, lactation). With most cows in the tropics housed indoors, physical activity is negligible.

The energy needed for maintenance at various live weights is shown in Table 6.1. These values include a 5% safety margin to take into account the energy required to harvest and chew the feeds. Tables 6.1, 6.2, 6.3, 6.4 and 6.6 present energy requirements in both Metabolisable Energy (ME) and Total Digestible Nutrients (TDN), calculated using the conversion factors in Chapter 4, by DE Burrell (pers. comm. 2003).

Table 6.1 Energy requirements for maintenance
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Live weight (kg)	Daily energy requirements	
	ME (MJ/d)	TDN (kg/d)
100	17	1.2
150	22	1.5
200	27	1.9
250	31	2.2
300	36	2.5
350	40	2.8
400	45	3.1
450	49	3.4
500	54	3.8
550	59	4.1
600	63	4.4

6.2.2 Activity

An small allowance for grazing and eating activity has been factored into the maintenance requirements in Table 6.1. In flat terrain, an additional 1 MJ ME (or 0.1 kg

TDN)/km should be added to provide the energy needed to walk to and from the dairy. In hilly country, this increases up to 5 MJ ME (or 0.4 kg TDN)/km walked throughout the day.

6.2.3 Pregnancy

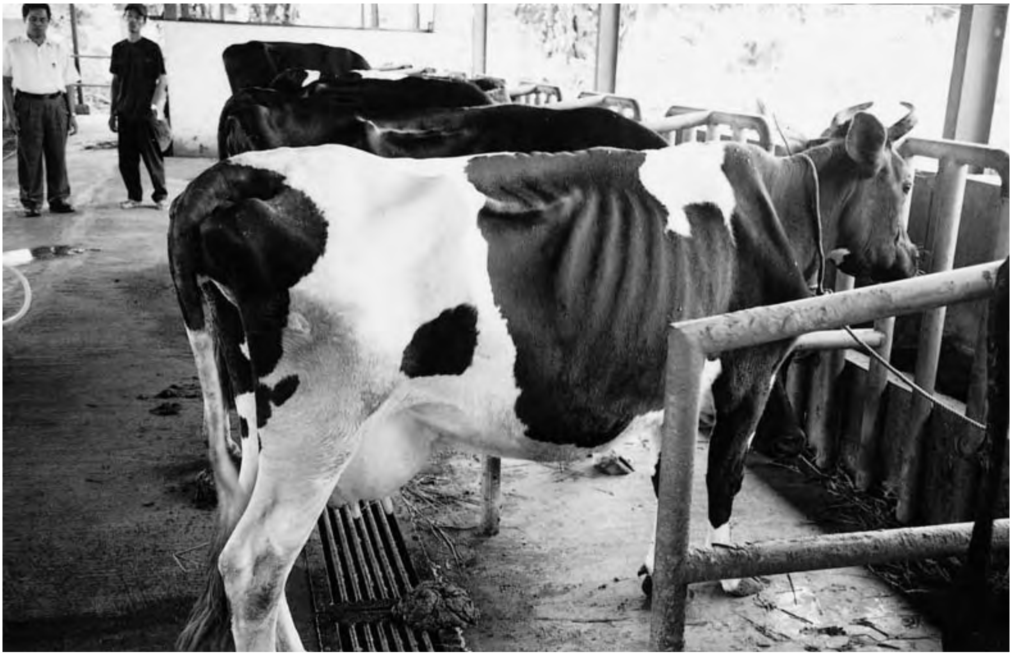
A pregnant cow needs extra energy for the maintenance and development of the calf inside her. From conception through the first five months of pregnancy, the additional energy required is about 1 MJ/d for each month of pregnancy. Energy requirements for pregnancy become significant only in the last four months (Table 6.2).

Table 6.2 Average daily energy requirements in the last four months of pregnancy
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Month of pregnancy	Daily additional energy required	
	ME (MJ/d)	TDN (kg/d)
Sixth	8	0.6
Seventh	10	0.7
Eighth	15	1.1
Ninth	20	1.4

6.2.4 Milk production

Energy is the most important nutrient to produce milk. The energy needed depends on the composition of the milk (ie fat and protein content). The following tables present the energy needed to produce 1 L of milk with a range of fat and protein tests, in both MJ of Metabolisable Energy (Table 6.3) and kg of Total Digestible Nutrients (Table 6.4). High-testing milk might need 7.1 MJ of ME (or 0.5 kg TDN)/L, whereas low-testing milk might need only 4.5 MJ of ME (or 0.3 kg TDN)/L of milk.



Lactating cows have high energy requirements, which are not being met on this farm in West Java, Indonesia.

Dairy industries in many tropical countries do not measure protein contents of milk delivered from small holder farmers, alternatively using Solids-Not-Fat (SNF) content to measure non-fat milk solids. Solids-not-fat comprises the protein, lactose and minerals in milk, with lactose and mineral contents being relatively stable. Assuming lactose is 4.7% and minerals 0.7%, milk protein can be calculated as follows:

Milk protein (%) = SNF% – 5.4.

Table 6.3 Energy needed per litre of milk of varying composition (MJ ME/L)
Metabolisable Energy (ME). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Fat (%)	Protein (%)									
	2.6	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**	**3.8**	**4.0**	**4.2**	**4.4**
3.0	4.5	4.5	4.6	4.7	4.8	4.8	4.9	5.0	5.0	5.1
3.2	4.6	4.7	4.7	4.8	4.9	5.0	5.0	5.1	5.2	5.2
3.4	4.7	4.8	4.9	4.9	5.0	5.1	5.2	5.2	5.3	5.4
3.6	4.9	4.9	5.0	5.1	5.1	5.2	5.3	5.4	5.4	5.5
3.8	5.0	5.1	5.1	5.2	5.3	5.3	5.4	5.5	5.6	5.6
4.0	5.1	5.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.8
4.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9
4.4	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9	6.0	6.0
4.6	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.1	6.2
4.8	5.6	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3
5.0	5.8	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4
5.2	5.9	6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5
5.4	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.7
5.6	6.2	6.2	6.3	6.4	6.5	6.5	6.6	6.7	6.7	6.8
5.8	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8	6.9	6.9
6.0	6.4	6.5	6.6	6.6	6.7	6.8	6.9	6.9	7.0	7.1

Table 6.4 Energy needed per litre of milk of varying composition (kg TDN/L)
Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Fat (%)	Protein (%)									
	2.6	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**	**3.8**	**4.0**	**4.2**	**4.4**
3.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
3.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
3.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
3.6	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
5.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
5.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
5.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
5.6	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5.8	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
6.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

The following steps and Tables 6.1 to 6.3 can be used to calculate daily metabolisable energy requirements for:

- a 550 kg cow
- housed, hence with no activity allowance
- in the sixth month of pregnancy
- producing 13 L of milk (containing 3.6% fat and 3.2% protein),

1. 59 MJ/d + 0 MJ/d + 8 MJ/d = 67 MJ/d (for maintenance, activity and pregnancy, respectively)plus
2. 5.1 MJ/L milk for 13 L (= 5.1 MJ × 13 L) or 66 MJ/d for milk production, hence
3. a total of 67 MJ/d + 66 MJ/d = 133 MJ/d.

6.2.5 Body condition

When an adult cow puts on body weight, it is mostly as fat. Some of this fat is apparent on the backbone, ribs, hip bones and pin bones and around the head of the tail. This extra subcutaneous fat gives rise to a system of body condition scoring by visual appraisal. A very thin cow might score 3 or lower while a fat cow might score 6 or greater (see Chapter 18 for a full description of body condition scoring).

An alternative to scoring the extra condition on a cow would be to weigh her. Weighing a cow to determine if she has put on condition is more accurate, because condition score is affected by the cow's body shape. More fat is needed to produce one extra body condition score on a large-framed cow than on a small-framed cow. It takes longer to notice visual changes in body condition (four weeks at least) than it does to monitor changes in live weight (one to two weeks). Table 6.5 shows how many kilograms are equivalent to a change in one condition score at different live weights. Generally, the amount of weight gain required to increase the cow's condition by one condition score is about 8% of the cow's live weight.

Table 6.5 The weight of one condition score on cows of different sizes
(Source: Target 10 1999)

Cow's approximate live weight (kg)	Additional weight to increase by one condition score (kg)
550	44
475	38
400	32

Energy is stored as fat when a cow gains body condition. Conversely, energy is released when body condition is lost, or taken off. For cows gaining weight, their daily energy requirements are more than those with stable weight, whereas for cows losing weight, their daily energy requirements are less.

The amount of energy needed for condition gain and how much is released when condition is lost is shown in Table 6.6. Gaining 1 kg in the dry period takes more energy than gaining it in late lactation. Although it is worthwhile for cows to gain condition when they are dry, it is more efficient to feed extra energy during late lactation to achieve the desired condition score prior to drying off the cow.

Table 6.6 The amount of energy needed or lost in a 1 kg gain or loss in body weight or condition
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Target 10 1999)

Change in body condition	Energy needed to gain 1 kg of weight (MJ ME or *kg TDN*)	Energy available from 1 kg of weight loss (MJ ME or *kg TDN*)
Late lactation gain	44 (*3.1*)	–
Dry period gain	55 (*3.9*)	–
Weight loss	–	28 (*2.0*)

The calculation of this extra energy needed and the number of days to gain body condition requires an estimation of a realistic rate of live weight gain. For example, a 550 kg cow requires 1936 MJ of metabolisable energy (44 kg/condition score × 44 MJ/kg live weight gain) to gain one condition score, which if gaining 0.5 kg/d live weight, requires feeding an additional 22 MJ/d for 88 days during late lactation.

Thus, the daily Metabolisable Energy requirements for the following example can be calculated from Tables 6.1 to 6.6

- a 550 kg cow
- housed, hence with no activity allowance
- one month after calving
- producing 20 L of milk (containing 3.6% fat and 3.2% protein)
- losing 0.5 kg/d live weight.

1 59 MJ/d + 0 MJ/d + 0 MJ/d – 59 MJ/d (for maintenance, activity and pregnancy)plus
2 5.1 MJ/L milk for 20 L (= 5.1 MJ/L × 20 L) – 102 MJ/d for milk production less
3 0.5 kg/d × 28 MJ/kg (= 0.5 × 28) or 14 MJ/d hence
4 a total of 59 MJ/d + 102 MJ/d – 14 MJ/d or 147 MJ/d.

For another cow, the Metablisable Energy requirements can be calculated:

- a 550 kg cow
- housed, hence with no activity allowance
- in the seventh month of pregnancy
- producing 10 L of milk (containing 3.6% fat and 3.2% protein)
- gaining 0.5 kg/d live weight.

1 59 MJ/d+ 0 MJ/d + 10 MJ/d = 69 MJ/d (for maintenance, activity and pregnancy) plus
2 5.1 MJ/L milk for 10 L (5.1 MJ/d × 10 L) = 51 MJ/d for milk production plus
3 0.5 kg/d × 44 MJ/kg (0.5 kg/d × 44 MJ/kg) = 22 MJ/d thus
4 a total of 59 MJ/d + 51 MJ/d + 22 MJ/d = 132 MJ/d.

6.2.6 Effect of climatic stress on energy requirements

Cold stress is unlikely to directly influence the energy requirements of milking cows in South-East Asia. When animals are heat stressed to the point that they are panting, however, their energy requirements for maintenance can be increased by up to 10%.

6.3 Protein

The amount of protein a cow needs depends on her size, growth, milk production and stage of pregnancy. However, milk production is the major influence on protein needs. Crude protein needs at different levels of milk production are shown in Table 6.7. As discussed earlier, protein is measured as crude protein, which is the sum of rumen degradable protein plus undegradable dietary protein.

Table 6.7 Crude protein needs of a cow at different stages of lactation
(Source: Target 10 1999)

Milk production	Crude protein requirements (%)
Early lactation	16–18
Mid-lactation	14–16
Late lactation	12–14
Dry	10–12

When calculating the protein requirements of the herd, crude protein, rumen degradable protein or undegradable dietary protein figures can be used. Remember though that requirements for rumen degradable protein and undegradable dietary protein are only 'guesstimates'. To work out how much rumen degradable protein and undegradable dietary protein is required, the protein requirements of the rumen microbes and of the cow need to be considered. The microbial protein made available (after it is flushed from the rumen) also needs to be calculated.

Any shortfall in protein can then be made from all protein sources (eg UDP). However, not all microbial protein or undegradable dietary protein eaten becomes available to the cow. Factors such as digestibility of amino acids reaching the small intestine as well as feed intake will influence the type and amount of protein used by the cow. As a result, rumen degradable protein and undegradable dietary protein requirements can be calculated estimates.

6.3.1 How milk production affects requirements for RDP and UDP

Above a certain level of milk production, some protein in the diet must be Undegradable Dietary Protein. There is a limit to the rumen's capacity to use Rumen Degradable Protein to produce microbial protein, which can then be flushed on to the small intestine for digestion. Microbial protein coming out of the rumen can sustain milk production up to 12 L/d. In other words, when milk production is 12 L/d or less, all the protein in the diet can be Rumen Degradable Protein (ie protein that the microbes can use). However, for milk production over 12 L/d, at least some protein in the diet must be Undegradable Dietary Protein. It is unlikely that cows fed good quality roughages and producing less than 30 L/d

Induced protein deficiency can lead to overfat and infertile cows (Malacca, Malaysia) (see Section 11.5.1).

will need to be supplemented with additional Undegradable Dietary Protein. However, with poorer quality forages, which are common in the tropics, Undegradable Dietary Protein supplements generally stimulate milk yields.

6.4 Fibre

Cows need a certain amount of fibre in their diet to ensure that the rumen functions properly and to maintain the fat test. The levels of fibre that cows need in their diet is shown in Table 6.8. The fibre requirements listed are the absolute minimum values. Acceptable levels of Neutral Detergent Fibre in the diet are in the range 30% to 35% of dry matter.

Table 6.8 The minimum percentage of fibre needed in a cow's diet for healthy rumen function (using three different measures of fibre)
(Source: Target 10 1999)

Fibre measurement	Minimum amount of dietary fibre (% DM)
Neutral Detergent Fibre	30
Acid Detergent Fibre	19
Crude Fibre	17

Low-fibre, high-starch diets cause the rumen to become acid. Grain poisoning (acidosis) may occur. Adding buffers such as sodium bicarbonate to the diet reduces acidity and hence reduces this effect. Buffers are usually recommended when grain feeding per day exceeds 4 to 5 kg grain/cow. Buffers are not a substitute for fibre. Thus, long-term feeding of low-fibre diets should be avoided.

6.5 Vitamins and minerals

Some farmers spend a great deal of money on vitamin and mineral supplements for their cows. Production benefits occur only when the supplements correct a deficiency. Before purchasing the vitamin and mineral supplements, it is important to find out whether a deficiency exists. In some instances, supplementing animals that do not have a deficiency may lead to poisoning and even death. The vitamin and minerals required by dairy cows are summarised in Appendix 4.

6.5.1 Vitamins

To the best of current knowledge, an oversupply of water-soluble vitamins will not harm cows. Any excess is simply excreted in the urine. However, fat-soluble vitamins (the important ones being Vitamins A, D, E and K) are stored in the cow's body, and an oversupply of Vitamin A or D can cause poisoning or death.

Vitamin A

Vitamin A is also called retinol. It is formed from betacarotene in the diet. It is required by the retina for good eyesight and is needed for tissue and bone formation, growth, milk production and reproduction. Vitamin A maintains healthy epithelium (eg the lining of the teat canal), so deficiencies may increase the incidence of mastitis infections. About 100,000 international units (IU) of vitamin A are needed per day per cow. Any surplus is stored in the liver for up to four months. Vitamin A deficiency is uncommon in cattle that are fed good-quality green forages but may occur on diets high in cereal grains or cereal straw or if cattle are fed on dry forages for more than six months.

Vitamin D

Vitamin D is formed in the skin when stimulated by sunlight. Vitamin D is required for calcium and phosphorus metabolism in the body. It stimulates calcium absorption in the small intestine. It also mobilises calcium stores from the bones. It can, therefore, be used to alleviate milk fever. Cows need 50,000 IU of vitamin D per day. Vitamin D deficiencies are very rare in stock fed green forages; however, it may become apparent in fully housed cows with little access to sunlight. Vitamin D toxicity (perhaps due to excessive treatment for milk fever) causes calcification of soft tissues, especially the aorta.

Vitamin E

Vitamin E, selenium and Vitamin A all help the cow's immune system to function properly. The immune system fights infections and helps cows clean up after calving. Cows need 1,000 IU of Vitamin E per day. Higher amounts may be required around calving time. Vitamin E deficiencies can lead to poor reproductive performance. Retained membranes, metritis, cystic ovaries and low conception rates have all been linked to Vitamin E deficiency. Vitamin E deficiency also causes muscle degeneration, stiffness and uncoordinated movement, and may cause early embryonic loss.

6.5.2 Minerals

Essential macrominerals

Macrominerals are those required in quantities of grams per kilogram of dry matter (g/kg DM) or per cent DM. They include calcium, phosphorus, magnesium, potassium, sodium, sulfur and chlorine.

Essential microminerals

Microminerals are those required in quantities of milligrams per kilogram of dry matter (mg/kg DM), or parts per million (ppm). They include cobalt, copper, iron, iodine, manganese, zinc, selenium and molybdenum. It is very difficult to estimate the mineral requirements of cows because the requirement varies according to the absorption efficiency of the mineral, the production stage and age of the animal, the environment and the interaction with other minerals.

Mineral deficiencies are less likely if green forages are the major part of the diet. High-producing herds fed diets high in cereal grain or maize silage may need added minerals.

7

How feed requirements change during lactation

This chapter:

Explains the changes in energy requirements and intake capacity of cows at different stages of lactation.

The main point in this chapter:

- the partitioning of energy to milk production and body condition changes with the stage of lactation
- the stages of lactation can be categorised into early, mid- and late lactation and the dry period
- each stage has different goals and therefore required different feeding strategies.

Several changes occur in cows as they progress through different stages of lactation. As well as variations in milk production, there are changes in feed intake and body condition, and stage of pregnancy.

Following calving, a cow may start producing 10 L/d of milk, rise to a peak of 20 L/d by about seven weeks into lactation then gradually fall to 5 L/d by the end of lactation. Although her maintenance requirements will not vary, she will need more dietary energy and protein as milk production increases then less when production declines. However, to regain body condition in late lactation, she will require additional energy.

If a cow does not conceive, she has no need for additional energy or protein during pregnancy. Once she becomes pregnant she will need some extra energy and protein. However, the calf does not increase its size rapidly until the sixth month, at which time the nutrient requirement becomes significant. The calf doubles its size in the ninth month, so at that stage a considerable amount of feed is needed to sustain its growth.

Cows usually use their own body condition for about 12 weeks after calving, to provide energy in addition to that consumed. The energy released is used to produce milk, allowing them to achieve higher peak production than would be possible from their diet alone. To do this, cows must have sufficient body condition available to lose, and therefore they must have put it on late in the previous lactation or during the dry period.

This chapter introduces the lactation cycle with its varying goals hence feeding strategies. Further chapters will enlarge on management to achieve these strategies.

7.1 Calving to peak lactation

Milk yield at the peak of lactation sets up the potential milk production for the year; one extra litre per day at the peak can produce an extra 200 L/cow over the entire lactation. The full lactation response to extra milk at peak yield varies greatly with feeding management during mid- and late lactation. There are several obstacles to feeding the herd well in early lactation to maximise the peak. The foremost of these is voluntary food intake.

At calving, appetite is only about 50% to 70% of the maximum at peak intake. This is because during the dry period, the growing calf takes up space, reducing rumen volume and the density and size of rumen papillae is reduced. After calving, it takes time for the rumen to 'stretch' and the papillae to regrow. It is not until weeks 10 to12 that appetite reaches its full potential.

If the forage is very moist, say with a dry matter content of only 12% to 17%, the rumen cannot hold sufficient fresh forage to meet the dry matter (DM) needs of the cow. Peak milk production occurs around weeks 6 to 8 of lactation. So, when a cow should be gorging herself with energy, she is physically restricted in the amount she can eat. Figure 7.1 presents the interrelationships between feed intake, milk yield and live weight for a Friesian cow with a 12-month intercalving interval, hence a 300-day lactation. Such a lactation cycle is more typical of temperate dairy systems rather than small holder tropical ones. However, as it is possible in the tropics, it has been included in this manual as a target.

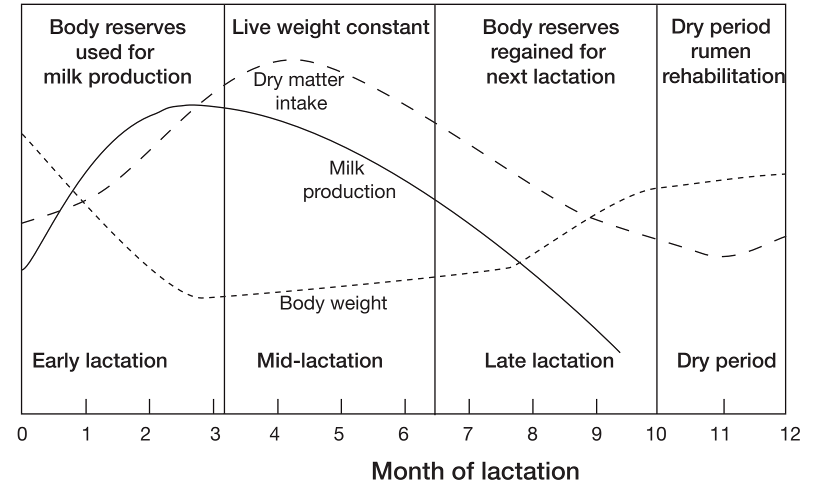


Figure 7.1 Dry matter intake, milk yield and live weight in a Friesian cow during the lactation cycle.

The level of feed intake is primarily determined by stage of lactation, but it can be manipulated. The feed intakes required for cows to meet their energy needs to produce target milk yields are shown in Table 7.1. By providing a high quality diet during early lactation (ie 10 versus 8 MJ/kg DM of ME), the physical restrictions of appetite would be reduced.

Table 7.1 Quantities of dry matter consumed by cows fed diets of different energy density and producing three levels of milk

Milk yield (L/d)	Daily energy requirement (MJ ME)	Daily required intake (kg DM)	
		8 MJ/kg DM	10 MJ/kg DM
13	125	15.6	12.5
17	146	18.2	14.6
20	161	20.1	16.1

The 20 L/d cow could probably not eat 20 kg DM of feed at 8 MJ/kg DM of Metabolisable Energy at any time during lactation, let alone in early lactation when intake is restricted. During early lactation, cows will produce more milk from more energy-dense feeds because they have to eat less DM to receive an equivalent intake of energy. Nutritional requirements generally exceed voluntary food intake until week 12, so body fat reserves are drawn upon to make up the nutrient deficit.

7.2 Peak lactation to peak intake

Following peak lactation, cows' appetites gradually increase until they can consume all the nutrients required for production, provided the diet is of high quality. Cows tend to maintain weight during this stage of their lactation (Figure 7.1).

7.3 Mid-lactation to late lactation

Although energy required for milk production is less demanding during this period because milk production is declining, energy is still important because of pregnancy and the need to build up body condition as an energy reserve for the next lactation.

It is generally more profitable to improve the condition of the herd in late lactation rather than in the dry period. While lactating, cows use energy more efficiently for weight gain (75% efficient compared to 59% efficient when dry).

7.4 Dry period

Maintaining (or increasing) body condition during the dry period is the key to ensuring cows have adequate body reserves for early lactation. Ideally, cows should calve in a condition score of at least 4.5, and preferably 4.5 to 5.5 (see Chapter 18 for details of scoring system). If cows calve with adequate body reserves, feeding management can plan for one condition score to be lost during the first two months of the next lactation.

Australian studies have found each condition score lost (between scores 3 to 6) in early lactation to be equivalent to 220 L of milk, 10 kg of milk fat and 6.5 kg of milk protein over the entire lactation (Robins *et al*. 2003). Furthermore, each additional condition score at calving can reduce the time between calving and first heat by 5 to 6 days. The sooner the cow begins to cycle, the sooner she is likely to get into calf.

If cows calve in poor condition, milk production suffers in early lactation because body reserves are not available to contribute energy. Dietary energy can be channelled towards weight gain rather being made available from the desired weight loss. For this reason, high feeding levels in early lactation cannot make up for poor body condition at calving.

8

Growing quality forages

This chapter:

Explains the milk production benefits from growing quality forages to reduce the level of concentrate fed to milking cows. The management of forages should aim to optimise both yield and quality.

The main points in this chapter:

- home grown quality forages usually provide the cheapest source of energy for milking cows
- milk responses to improving forage quality can be very large, up to 4 L/cow/day
- the four basic principles of growing good quality forages are:
  1. select the most appropriate forage species for the region
  2. prepare the forage production area for sowing
  3. manage the crop with adequate fertiliser to optimise growth and quality
  4. harvest the crop at the best stage of maturity for nutritive value.

Although this manual is specifically about feeding dairy stock, chapters have been included about growing and conserving quality forages. The key to profitable small holder dairying is to utilise sown forages first and then supplement milking cows with concentrates and other forages to overcome shortfalls in nutrients to achieve target milk yields.

Economic pressures decree that small holder dairy farmers zero graze or ‘cut and carry’ the forages to their stock. Usually, when cut forage is given, the nutritive value of forage is inferior to that grazed by stock, when they can select a better quality diet of leaves and less mature stems. Therefore, grazing cows have better milk production and reproductive performance than stall-fed cows. Aminah and Chen (1991) concluded that in the tropics, grazing systems can yield 15% more milk (9,700 versus 8,400 L milk/ha per year), which may partly explain the low milk yield of small holder dairy farmers.

The basis of economic dairy farming is producing and utilising quality forages. To maintain milk composition, milking cows require diets comprising 30% to 40% forages (on a dry matter basis) and forages are generally cheaper than concentrates. Milking cows have very high nutrient requirements and poor quality forages will just not supply them because of the physical limitations of rumen capacity. Furthermore, the physical demands of hand harvesting and carrying forages to stalled cows also reduces the likelihood of cows being supplied with sufficient quantities of forages. As most forages are harvested by hand, tall erect forage species are preferable to prostrate species. Forage quality can be ensured by selecting improved varieties of forages with optimum agronomic practices, such as described in this chapter.

8.1 Production benefits from good quality forages

It is very difficult for small holder dairy farmers to provide a year-round supply of good quality forages to their milking cows. Ideally, each milking cow should be provided with 50 kg/d of fresh forage containing at least 10 MJ/kg DM of Metabolisable Energy (ME) and 16% protein. During the wet season, forages grow so quickly that they are often too mature and have reduced feeding quality by the time they are harvested. In the dry season, there is generally a shortage of green forage, so many farmers feed forage by-products such as rice straw, banana leaves and sugar cane tops. In areas growing sweet corn, maize stover may be available for much of the year (either as fresh stover or maize stover silage), but it is generally not sufficiently high in energy content and is also very low in protein content.

Cultivated forage crops have many benefits to small holder dairy farmers. They:

- improve forage supplies and diet quality
- provide nutrients to the soil such as nitrogen from legumes and organic matter from grasses
- reduce soil erosion and shade soil from direct sunlight and desiccation
- suppress weeds and reduce pests and diseases in food crop rotations
- provide bulk feed.

Cultivated forages can be perennial (eg Napier grass) or annual (eg forage maize). Throughout this manual, the name ‘maize’ rather than ‘corn’ will be used. Forages can be grown in pure stands or as mixed swards.

8.1.1 Overcoming the high cost of concentrates

Compensating for low supplies of forage by feeding more concentrates is generally less profitable because on an energy basis, concentrates cost more. It is important to compare feeds on an energy basis, rather than their cost per kilogram fresh or per kilogram of dry matter. Data for two countries with differing energy systems and currencies are presented in Tables 8.1 and 8.2.

Thailand and Vietnam have been selected because of the difference in magnitude of their currency units (see Appendix 3 for currency conversion of other South-East Asian currencies) and the different energy systems routinely used. Thai dairy specialists use Total Digestible Nutrients (TDN) while Vietnamese dairy specialists use Metabolisable Energy (ME). Full descriptions of these units of energy are presented in Chapter 4.

Table 8.1 presents the typical costs for forages and concentrates in Thailand calculated as Thai Baht (Bt)/kg of Total Digestible Nutrients while Table 8.2 presents typical costs in Vietnam, expressed in Vietnam dong (VND)/MJ of Metabolisable Energy.

In both cases the cheaper forage is home grown while the expensive forage is purchased during the dry season. The cheap and expensive concentrates represent the two extreme prices to purchase formulated mixtures during the year.

Table 8.1 Comparing feed energy costs in Thailand (in Bt/kg TDN) for forages (20% DM, 60% TDN) with formulated concentrates (90% DM, 70% TDN)
Thai baht (Bt); Total Digestible Nutrients (TDN).

Feed	Cost for fresh feed (Bt/kg)	Cost for dry feed (Bt/kg)	Cost for TDN (Bt/kg)	Relative energy cost (%)
Forage				
Cheap	0.5	2.5	4.2	100
Expensive	1.0	5.0	8.3	198
Concentrate				
Cheap	5	5.6	8.0	190
Expensive	7	7.8	11.1	264

Table 8.2 Comparing feed energy costs in Vietnam (in VND/MJ of ME) for forages (20% DM, 9 MJ/kg DM of ME) with formulated concentrates (90% DM, 11 MJ/kg DM of ME)
Vietnam dong (VND); Metabolisable Energy (ME).

Feed	Cost for fresh feed (VND/kg)	Cost for dry feed (VND/kg)	Cost for ME (VND/MJ)	Relative energy cost (%)
Forage				
Cheap	100	500	56	100
Expensive	200	1000	111	198
Concentrate				
Cheap	2000	2222	202	361
Expensive	2500	2777	252	450

The last column of each table presents energy costs relative to that of cheap forages. Compared to the energy sourced from home grown forages, formulated concentrates cost two to three times more in Thailand and three to four times more in Vietnam. Similar conclusions are reached when comparing energy costs of such feeds in other countries in South-East Asia.

8.1.2 Milk responses to improving forage quality

Possible improvement in milk yield arising from feeding higher quality forages are presented in Table 8.3. These data are for a 450 kg, non-pregnant cow with zero live weight change fed the same daily quantity of concentrate.

Depending on feeding levels, cows can produce up to an extra 4 L/d of milk through changing forages from say, maize stover or a poorly managed mature stand of grass to a well-fertilised forage such as Napier grass harvested every 4 weeks.

The financial benefits from such milk responses could be utilised either through:

1. feeding the same quantity of concentrates and producing additional milk, or
2. feeding less concentrates for the same milk yield.

Such a decision would depend on the relative cost of concentrates and returns for milk.

Table 8.3 Milk responses through improving forage quality from 50 to 60% TDN (or from 7.4 to 9.2 MJ/kg DM of ME)
Metabolisable Energy (ME); Total Digestible Nutrients (TDN).

Forage intake		TDN intake from forage (kg/d)			Marginal milk response per day (L/hd)
Fresh (kg/d)	DM (kg/d)	Forage quality in TDN (%) or *ME (MJ/kg DM)*			
		50% (*7.4*)	55% (*8.3*)	60% (*9.2*)	
30	6.0	3.0	3.3	3.6	2.1
40	8.0	4.0	4.4	4.8	3.1
50	10.0	5.0	5.5	6.0	3.7
60	12.0	6.0	6.6	7.2	4.2

8.2 The four basic principles of growing quality forages

The four basic principles of growing quality forages are:

1. select the most appropriate forage species for the region
2. prepare the forage production area for sowing
3. manage the crop, particularly with adequate fertiliser to optimise growth and quality
4. harvest the crop at the best stage of maturity for nutritive value.

8.2.1 Selection of forage species

The forage must suit the local conditions. Farmers should ask the following questions when selecting their forage species:

- are there advantages over local varieties?
- have they been tried and found successful in the region?
- do they suit local farming systems and ecological conditions?
- what extra inputs are required, such as seed costs, labour and fertilisers?
- will their extra cost return a profit?
- what are the risks of crop failure?
- do the seeds come from a reliable source of supply?

Species recommended for small holders in South-East Asia

No forages grow well everywhere. Some grow well in acidic soils while others do not. Some grow well in cool areas, while others do not. Forages can survive in areas where they are not adapted but they will not thrive. It is important to choose forages that are adapted to local soils and climate.

Important climatic factors affecting forage adaptation are the length of the growing season, temperatures, soil fertility, soil pH and drainage.

During the late 1990s an Australian-funded project called ‘Forages for smallholders project’ established trial sites throughout South-East Asia to involve farmers in the selection of the most suitable forages for livestock feeding in upland farming systems. The farmers needed to access forages that:

- were adapted to the climate and soils
- suited their intended use
- fitted into their particular farming system.

Horne and Stur (1999) identified a range of forages on their suitability to various climates, soil fertility levels and farming systems and these are listed in Table 8.4, with further details in Table 8.5.

Table 8.4 An inventory of forages for small holder livestock farmers for different climates, soil fertility and farming systems in South-East Asia

Key to table; **, highly suitable; *, possible, –, not suitable

Climate:1, wet tropics with no or short dry season; 2, wet/dry tropics with long dry season.

Soil fertility: 1, fertile and neutral to moderately acid soils; 2, moderately fertile and neutral to moderately acid soils.

Farm system: 1, cut and carry; 2, grazed plots. (Source: Horne and Stur 1999)

Species	Variety	Climate		Soil		Farm	
		1	2	1	2	1	2
Grasses							
Andopogan gayanus	Gamba	*	**	*	*	**	*
Brachiaria brizantha	Marandu, Karanga, Serengeti	*	**	*	**	**	*
Brachiaria decumbens	Basilisk	*	**	*	**	*	**
Brachiaria humidicola	Tully, Yanero	**	*	*	*	*	**
Brachiaria ruziensis	Ruzi	**	–	**	*	*	**
Panicum maximum	Si Muang	**	*	**	*	**	*
Paspalum attratum	Terenos	**	–	*	**	**	*
Pennisetum purpureum (and hybrids)	Napier, Mott, King	**	–	**	*	**	–
Setaria sphacelata	Lampung, Solander	**	*	**	*	**	*
Legumes							
Arachis pintolai	Itacambira, Amarillo	**	–	**	**	–	*
Calliandra calothyrsus	Besikah	*	–	*	**	**	–
Centrosema pubescens	Barinas	**	*	**	*	*	–
Centrosema macrocarpum	Ucayali	**	*	**	*	*	–
Desmanthus virgatus	Chaland	**	–	**	*	**	–
Desmodium cinera	Las Delicias	*	*	*	*	**	–
Gliricidia sepium	Retalhulen, Belan Rivas	**	**	*	**	**	–
Leuceana leucocephala	K636, K584	**	**	**	*	**	*
Stylosanthes guianensis	Stylo 184	**	*	**	**	**	*

This Chapter will discuss the management of Napier grass, Guinea grass and the annual forage sorghums in more detail.

Napier (or Elephant) grass

Napier grass (*Pennisetum purpureum*) is a common grass cultivated for feeding dairy cows in many countries in South-East Asia. Napier, King and Mott are all varieties of Elephant grass. King grass is taller, leafier and more productive in soils of high fertility, but is less robust and persistent under declining fertility or during dry periods. Mott, often called dwarf Napier grass, has more tillers and is leafier than Napier grass, and is more suited to growing in hedgerows than other varieties of Elephant grass.

Napier grass is one of the most productive grass crops in the world, in one instance yielding 85 t DM/ha per year in the Caribbean, when fertilised over the year with

Table 8.5 Characteristics of forages suitable for small holder farmers in South-East Asia

(Source: Horne and Stur 1999)

Grasses	Characteristics
Andopogan gayanus	Tall grass for cutting, stays green in dry season, grows well in infertile acid soils, becomes stemmy if not cut frequently
Brachiaria brizantha	Tall grass suitable for cutting, grows well in moderately fertile soils, stays green in dry season, should not be fed to goats, sheep or young cattle
Brachiaria decumbens	For grazing and cutting, adapted to wide range of soils, stays green in dry season, should not be fed to goats or sheep
Brachiaria humidicola	Vigorous creeping grass, can tolerate heavy grazing, can grow in very infertile soils, can tolerate waterlogging, lower quality than other Brachiaria species
Brachiaria ruziensis	Established easily from seeds or cuttings, provides high quality forage, needs high soil fertility, poor persistence in poor soils, not adapted to long dry seasons
Panicum maximum	Tall grass for cutting, suited to more fertile soils, produces high quality forages, must be regularly fertilised, becomes stemmy if not cut frequently, not suited to long dry seasons
Paspalum attratum	Tall grass for cutting, grows well on infertile soils, wet tropics with no dry season, can tolerate water logging, very leafy, not suited to long dry seasons
Pennisetum purpureum (& hybrids)	Very tall grasses for cutting, highest yielding species with high soil fertility and irrigation, high quality seed, will not persist without fertilising, not suited to long dry seasons, becomes stemmy if not cut frequently
Setaria sphacelata	Erect grass for cutting, soft and palatable leaves, can survive in poor soils, can tolerate water logging for short periods, grows well in cool areas, needs good moisture and soil fertility or high production, some leaf diseases in humid tropics, should not be fed to horses
Legumes	
Arachis pintolai	Low growing stoloniferous legume, very persistent under hard grazing, good ground cover under trees, high quality livestock feed, needs moderate soil fertility, not suited to long dry seasons
Calliandra calothyrsus	Good tree legume for cooler climates, can grow in acid soils, high leaf yield under cutting, good fire wood, palatable only when fresh, needs to be planted from seeds, slow seedling growth
Centrosema pubescens and Centrosema macrocarpum	Twining legume, good for weed control, grow well with tall grasses for cut and carry, not adapted to long dry seasons, need moderately fertile, well-drained soils, needs to be planted from seed.
Desmanthus virgatus	Shrubby legume for cutting, grows best in fertile clay soils, high quality feed, used for leaf meal production, easy seed production, not suited to acid soils, needs to be planted from seed
Desmodium cinera	Fast growing shrub for cutting, suited to hedgerows, good quality feed, best for wet tropics, short lived (2–3 yr), needs to be planted from seeds
Gliricidia sepium	Easy to plant from stem cuttings, useful as living fence, grows well in moderately acid soils, low palatability for cattle, susceptible to pests
Leuceana leucocephala	Highly productive, tolerant to heavy grazing and cutting, high quality feed supplement, good fire wood, good dry season growth, not for acid infertile soils, not for monogastric animals, susceptible to psyllid insects, needs to be planted from seed
Stylosanthes guianensis	Erect robust legume for cutting, highly productive, good quality feed, many uses including leaf meal production, widely adapted to low fertility and acid soils, leaf stays green into dry season, resistant to the fungal disease anthracnose, short lived (2-3 yr), not tolerant to heavy grazing or frequent cutting

900 kg N/ha. With the best management, Napier grass can produce 50 t DM/ha per year, enough to feed nearly 14 milking cows every day with 50 kg/cow fresh forage. More typical annual yields are 20 to 30 t DM/ha, depending on fertiliser regimes.

Napier grass is best suited to high rainfall areas and will not persist without fertilising. It is not suited to long dry seasons and becomes very stemmy if not cut frequently. Although Napier grass can produce high yields of good quality forage when fertilised by animal manure only, it will produce even higher yields with a fertiliser program of urea, and possibly superphosphate in some situations.

Napier grass is best grown from runners, 1 to 2 cm in diameter with 3 to 4 nodes cut from the middle of a 9 to 12-month-old stem. It should be planted early in the wet season into a ploughed and harrowed field. At sowing, 500 kg/ha of NPK (nitrogen, phosphorus, potassium) fertiliser should be incorporated, with an annual maintenance dressing of 200 to 300 kg/ha of NPK fertiliser. After each harvest, 100 kg/ha of urea should be applied (STOAS 1999).

Napier grass should be harvested down to 20 cm, when it reaches about 100 cm in height. This can take 25 to 30 days in the wet season or 50 to 60 days in the dry season. It should be allowed to flower just prior to the last wet-season harvest. To maintain good quality forage, it must be replanted every three to four years.

Annual forage sorghums and millets

Several of the latest varieties of these annual sorghum and millet forages have been tested recently in Indonesia (J Moran unpublished 2002):

- Jumbo, which is a late flowering sorghum × Sudan grass hybrid. It has a high initial growth rate and a rapid regrowth after cutting.
- Sugargraze, which is a sweet sorghum hybrid suitable for silage making. It is a high yielding crop with high sugar levels and good resistance against leaf diseases.
- Chopper, which is a grain sorghum hybrid bred specifically for silage. It is a tall, late maturing crop with a large, white, grain-filled head. It is ready for harvest between 85 and 95 days, with high yields and good protein and energy levels.
- Nutrifeed, which is a pearl millet hybrid with no prussic acid (cyanide which can kill cows). It has a fast regrowth and prefers well-drained soils.

Results from our evaluations, which included King grass as a control, are presented in Table 8.6. These particular forages were fertilised with a mixture of manure (18.5 t/ha) and 150 kg/ha of fertiliser (27:7:7:1 for NPKS), which provided 37 kg N, 10 kg P, 10 kg K and 1.5 kg S per ha.

The highest yielding forage was Jumbo, closely followed by Sugargraze. King grass produced the best quality forage, while all crops had similar energy and protein levels. These forages were all harvested on the same day, however, and not at their optimum stage of maturity for quality. For example, Jumbo and Sugargraze were harvested above their optimum heights while Chopper was harvested before it had produced any seed heads.

Table 8.6 Dry matter yields and quality of 50-day-old forages in Indonesia (West Java)
dry matter (DM); Neutral Detergent Fibre (NDF); Metabolisable Energy (ME); Total Digestible Nitrogen (TDN). (Source: J Moran, unpublished 2002)

Forage	DM yield (t/ha)	DM (%)	Protein (%)	NDF (%)	DM digestibility (%)	ME (MJ/ kg DM)	TDN (%)
Jumbo	26.6	14.1	14.5	74.3	51.3	7.2	49
Sugargraze	23.4	12.2	11.9	74.8	52.7	7.4	50
Chopper	7.7	11.6	12.9	75.2	54.9	7.8	52
Nutrifeed	7.4	12.4	13.6	74.4	53.2	7.5	51
King grass	7.7	12.9	16.0	69.8	55.7	7.9	53

Comparing King and Guinea grass

Although Napier grass has traditionally been considered one of the most suitable grasses for intensive animal production, its reliance on high soil fertility and regular rainfall limits its applicability. There is a renewed interest in Guinea grass (*Panicum maximum*) as an alternative pasture crop.

Like Napier, Guinea grass is an erect perennial grass but does not grow as tall as Napier grass (1–1.5 m compared to up to 7 m in height). Guinea grass is adapted to both the tropics and subtropics and is even tolerant to shading, and hence has a role in agroforestry plantations. In certain situations its yield can be equivalent to Napier grass.

For example in Queensland, with fertiliser regimes of 250 kg N/ha at establishment and 200 kg N/ha over the following five months and harvested every four weeks, Napier grass yielded 10.1 t DM/ha over 12 weeks compared to 9.8 t DM/ha with Guinea grass (Lisson, pers. comm. 2004). Increasing harvest intervals to eight weeks increased total DM yields over two harvests to 19.3 t/ha in Napier and 22.0 t/ha in Guinea grass. Such DM growth rates, ranging from 0.8 to 1.4 t DM/wk, are considerably higher than those in Table 8.7 (0.2–0.7 t DM/wk), highlighting the beneficial effects of increased applications of fertiliser nitrogen.

The performance of Napier grass and Guinea grass was compared (Table 8.7) in South Vietnam (Mann 2001). The variety of *Pennisetum purpureum* was King grass while the variety of *Panicum maximum* was small leaf Guinea grass cv 280. They were planted by cuttings into a sandy acid soil after fertilising with 10 t/ha of manure plus 100 kg/ha each of phosphorus and potassium. Nitrogen fertiliser was applied five days after planting and after each harvest, to supply 200 kg/ha per growing season with 50 kg N at planting and the remainder divided equally between harvests. Plots were slashed to 10 cm eight weeks after planting, then at various harvest intervals during the following 24 weeks. Grass from three of the harvest treatments was fed to Friesian heifers, first to appetite (20% above consumption) for 12 days, and second, during digestibility trials, when restricted (85% of *ad libitum* intake).

Yields of dry matter were consistently lower in King grass, being 39%, 41%, 57% and 70% of those in Guinea grass with increasing maturity. However, King grass had the better forage quality – lower contents of dry matter, Neutral Detergent Fibre and and the higher contents of Crude Protein. This occurred despite Guinea grass having a greater proportion of leaf blade.

In the feeding trials, intakes of dry matter were consistently higher in Guinea grass even though their digestibilities of dry matter (and hence Metabolisable Energy content) and Crude Protein were lower than those in King grass. The grasses generally maintained their nutritive value up to harvest intervals of six weeks, after which energy and protein values deteriorated more rapidly. Despite their higher contents in King grass, total yields of energy and digestible protein were considerably lower than in Guinea grass, being 43% to 57% and 50% to 58%, respectively. Yields of digestible protein were highest in immature grasses whereas yields of Metabolisable Energy were generally higher in more mature grasses.

Table 8.7 Forage yield and quality of King and Guinea (cv 280) grasses at various harvest intervals
dry matter (DM); Crude Protein (CP); live weight (LWT); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF). (Source: Mann 2001)

	Grass species	Harvest interval (wks)			
		4	6	8	10
Forage trial					
DM yield (kg/ha/wk)	King	179	236	345	525
	Guinea	460	564	598	747
DM content (%)	King	13.2	13.2	14.9	17.7
	Guinea	19.4	20.4	22.8	23.8
CP content (%)	King	15.5	11.4	7.7	6.8
	Guinea	12.6	9.7	7.2	6.9
NDF content (%)	King	63.6	69.6	72.6	75.3
	Guinea	73.8	76.8	77.6	79.3
Leaf blade (% plant DM)	King	71	60	50	44
	Guinea	81	73	71	60
Feeding trials					
DM intake (kg/100 kg LWT)	King	2.06	2.18	2.00	–
	Guinea	2.48	2.42	2.25	–
DM digestibility (%)	King	65.2	64.6	57.7	–
	Guinea	60.4	61.6	57.8	–
CP digestibility (%)	King	69.7	53.7	44.9	–
	Guinea	60.5	52.5	47.1	–
ME content (MJ/kg DM)	King	9.1	9.0	7.8	–
	Guinea	8.3	8.5	7.8	–
Digestible CP yield (kg/ha per wk)	King	19.3	14.4	11.8	–
	Guinea	35.0	28.6	20.3	–
ME yield (000 MJ/ha per wk)	King	1.63	2.12	2.69	–
	Guinea	3.82	4.79	4.66	–

Frequent harvesting can reduce stand life as in this study, the proportion of dead clumps in King grass increased from 0.4% with 10-week harvesting to 3% with 4-week harvesting. However, there were no dead clumps of Guineas grass in all harvest treatments.

There was little effect of harvest interval on voluntary intake, partly because the heifers had ample opportunity to select the more palatable forage since it was fed at 20% above consumption. Guinea grass, having the greater proportion of leaf, was consumed in greater amounts than King grass.

Optimum harvest management is aimed at achieving the highest biomass yield, which satisfies the animal's needs, usually determined by animal performance. With regard to yields of Metabolisable Energy, optimum cutting frequency seems to be around six weeks, whereas from animal performance, Guinea grass should be harvested every four weeks while Mann (2001) recommended that harvesting King grass can be lengthened to six weeks.

8.2.2 Preparing for sowing

The forage production area may need to be ripped to improve water infiltration. Some forages can be grown from runners or stem cuttings, while others require seeds.

Guidelines for seed bed preparation are:

- they can be roughly prepared with seed broadcast by hand and rolled in
- there can be finely prepared for sowing in rows and with weeding after germination
- seeds can be germinated in a nursery and then transplanted into the forage growing area
- legumes vary in seed bed requirements and have specific rhizobia requirements (to synthesise their own nitrogen from the soil)
- the area must be protected against intruders, such as ants, chickens, wild birds and livestock
- consideration should be given to sowing forages under shade to potentially improve yields through less desiccation of the soil during the dry season.

Depending on availability of land, forages can be cultivated on a large scale, in small plots, in strips (eg along terrace banks), in a multistorey garden (eg in forests or plantations). With very limited land, forages can be integrated into food crops, such as *Leucaena* trees along fence lines.

After the land is prepared, planting should proceed without delay to minimise growth of weeds. It is best to prepare the land after the first rains and have adequate stocks of seeds or runners available for rapid sowing.

Optimum sowing depths and sowing rates vary with forage species. With low seeding rates, seeds can be mixed with a carrier material, such as sawdust, for ease of sowing. The need to regularly prepare seedbeds for sowing could increase soil erosion in high rainfall areas.

Plant nutrient requirements and weed and pest control must be addressed to optimise forage yield and quality. Maintaining pure stands may not be important for forages provided the invading forages do not greatly reduce yields, are still palatable, non toxic and of good quality.

8.2.3 Fertilising the crop

To produce annual yields of 150 t fresh pasture/ha, Napier or Guineas grasses require a fertiliser program that supplies 880 kg N, 252 kg P and 756 kg K/ha over the year (Aminah and Chen 1991). One of the best ways to achieve high forage yields is through using inorganic fertilisers, such as urea and superphosphate. Using cow manure as the only source of nutrients for forages will not supply enough nitrogen and and phosphorus to fast-growing tropical forage grasses.

Fertilisers will boost yield and nutritive value of forage regrowth. Table 8.8 presents data where a tropical pasture sward was fertilised once at two rates (0 and 72 kg N/ha) then harvested weekly. Forage regrowth was two to three times higher on the fertilised sward, as were pasture protein contents.

Table 8.8 Yield and protein content of tropical pasture fertilised at two rates (0 and 72 kg N/ha) then harvested weekly

Fertiliser (kg N/ha)	DM yield (kg DM/ha)		Protein content (%)	
	0	72	0	72
Harvest interval (weeks after fertilising)				
1	200	700	11	16
2	600	2300	10	14
3	1300	2100	9	12
4	1400	2600	8	11

Table 8.9 presents the results of a study of Napier grass fertilised at two rates (0 and 110 kg N/ha at cutting) and harvested either every 40 or 60 days. The forage was conserved as hay and fed to buffalo bulls.

Fertiliser nitrogen improved forage quality, particularly at the shorter cutting interval, allowing stock to consume more as hay. If fed to milking cows, the less mature, fertilised forage would have increased milk response. Even though tropical pastures can respond to higher fertiliser applications, Aminah and Chen (1991) considered the optimum annual level to be 300 kg N/ha, split into five equal applications over the year.

Table 8.9 Quality of Napier grass fertilised at two rates (0 and 110 kg N/ha) and harvested after 40 or 60 days regrowth

dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). Forage was conserved as hay and fed to buffalo bulls.

Regrowth	40 days		60 days	
Fertiliser (kg N/ha)	0	110	0	110
Protein (%)	8.6	12.7	7.1	10.8
NDF (%)	70.6	73.6	78.3	79.1
ME (MJ/kg DM)	7.2	8.4	6.6	6.3
TDN (%)	49	56	46	44
Hay intake (kg DM/day)	7.5	8.9	6.5	7.8

Investing in fertilisers

Fertilisers cost money, but they return more through improved yields and quality of forage, hence more milk. Provided other soil nutrients are not limiting plant growth, urea fertiliser can produce an extra 9 kg forage DM/kg urea or 18 kg DM/kg N applied. When harvested and fed to milking cows, this extra forage can yield an additional 9 L milk/kg urea N (STOAS 1999).

Table 8.10 presents an economic analysis of fertiliser responses in Thailand and Indonesia, based on typical urea prices and milk returns in these countries.

Clearly in both countries investing in urea fertiliser is a good business decision with benefit:cost ratios of 4:1 or 8:1. This extra income can arise from more milk per cow and/ or milking more cows per hectare.

Table 8.10 Economic benefits through using urea to fertilise forages fed to milking cows in Thailand and Indonesia, assuming the marginal milk response to urea is 9 L milk/kg urea N

Country (currency unit)	Urea cost		Milk return		Benefit:cost ratio
	per kg	per kg N	per L	per kg N	
Thailand (Bt)	6	13	12	108	8.3
Indonesia (Rp)	1800	3910	1720	15480	4.0

Higher quality forages mean that less concentrates need to be fed to produce the same amount of milk. For example in Thailand, the usual recommendation is to feed 1 kg concentrate per 2 L of milk. Dairy farmers in Latin America feeding well-fertilised Napier grass need only feed 1 kg concentrate per 4 L milk produced (ie half the rate of many small holder farmers in South-East Asia). Furthermore, they can feed 14 milking cows/ha of Napier grass, each producing 15 L/d supplemented daily with 4 kg/cow of concentrates.

Can cow manure supply sufficient fertiliser?

One major limitation of forage production on most small holder dairies in South-East Asia is the poor adoption of inorganic fertilisers. Use of cow manure only to fertilise grasses is common practice in most dairying areas with most farmers not even aware of the economic gains through using inorganic fertilisers. Cow manure supplies organic matter to the forage area, but insufficient nitrogen to maximise forage yields and quality. The following nutrient audit shows that small holder dairy farmers should apply annually at least 100 kg urea/ha to their forage production area, in addition to the recycled manure.

In the case study it is assumed that each small holder farmer has 4 milking cows, with a calving interval of 15 months, and uses all the manure to fertilise forage supplies. Each lactation each milking cow produces 3000 L of milk and consumes 1500 kg of purchased concentrates. Milk contains 0.5% N and 0.1% P while concentrates contain 16% protein (2.6% N) and 1% P.

Choi *et al.* (2004) found each 450 kg lactating cow produced 46 kg/d of manure (32 kg faeces + 14 kg urine) containing 12.9% DM and excreting a total of 0.15 kg N, 0.04 kg P and 0.08 kg K each day. The ratio of total nutrients output in faeces:urine for N are 62:38, for P are 99:1 and for K are 50:50. These data will allow the calculation of nutrient audits if not all the manure is recycled onto the forage growing area. The nitrogen in manure can be lost through volatilisation, nitrification, leaching and surface runoff. The phosphorus in manure can be lost through leaching, surface runoff and soil erosion.

Cow manure alone does not provide sufficient soil nutrients for optimum forage growth (Binh Duong province, Vietnam).

Nutrients leaving the case study farm via milk sales are 15 kg N and 3 kg P/cow per lactation. Nutrients entering the farm through purchased concentrates are 39 kg N and 15 kg P/cow per lactation. By recycling all the manure onto the forage production area, the farm then has a positive balance of 24 kg N and 12 kg P/cow per lactation that is available to grow forages, produce replacement stock (pregnancy and rearing) and grow out the milking cows.

Assuming each milking cow consumes 3 t forage DM/lactation which contain 8% protein (1.3% N) and 0.3% P, each cow then consumes 39 kg N and 9 kg P/lactation from forages. Therefore, every lactation, each cow will remove 15 kg more N than is returned via manure, while there is an excess of 3 kg P from the recycled manure. This does not take into account the loss of N and P through sale of calves and cull cows.

This case study small holder farmer then has a positive phosphorus audit of 36 kg/lactation (or 29 kg P/yr), which is available to provide phosphorus for the non-milk farm products. However, each lactation there is a negative nitrogen audit of at least 60 kg N/lactation, equivalent to 48 kg N/yr, which must be imported onto the farm in the form of nitrogen fertilisers. Assuming the 12 t DM from forages was grown on 1 ha land, from forages yielding annually 9.6 t DM/ha, the forage crop would require at least an additional 100 kg urea/ha over the year on top of the recycled manure. This is likely to be more because much of the nitrogen from urine would be lost through volatilisation and leaching. Effluent disposal systems to minimise such nitrogen losses are discussed in Chapter 19.

Other sources of soil nutrients

There may be other nutrient sources available for use as fertilisers, such as agro-industrial by-products, which could be price competitive with inorganic fertilisers. One such example is a by-product of production of monosodium glutamate (a commonly used

A liquid by-product of monosodium glutamate production, stored in this dam, is a cost effective source of fertiliser nitrogen (Binh Duong province, Vietnam).

feed additive for Asian cooking), sold in South Vietnam as an alternative fertiliser. This product, a liquid that is pumped into ponds for storage (see photo below), can be delivered on-farm for the equivalent of 50 Vietnam dong (VND) per litre, and it contains 3.5% N. Urea fertiliser, however, costs 3,000 VND/kg and contains 46% N. The price per kilogram of nitrogen of these two products are then 1,430 and 6,520 VND, respectively, making urea four to five times more expensive as a source of nitrogen. Before selecting a cheaper fertiliser source, however, complete analyses of the product needs to be made to ascertain whether there may be other constituents which may adversely affect forage yield and quality when the product is applied to supply a predetermined amount of N, P or K.

Simple on-farm fertiliser demonstrations

The calculations in the previous sections are based on a series of assumptions, which will vary depending on the efficiency of manure recycling, particularly how much of the urine actually reaches the forage area. It is one thing to calculate the nitrogen deficit and another to convince farmers to purchase fertiliser for their forage areas.

Many dairy farmers in Western countries base their fertiliser decisions on the nutrient status of the soils. This is not possible for most small holder farmers in South-East Asia because of the lack of soil testing laboratories and/or the cost of such analyses. However, such advice may be available from local agronomists who service cash crops such as rice or cassava.

A visual and very simple method of assessing the likely response to fertiliser applications is to demonstrate it to farmers through test strips, whereby they apply different fertiliser regimes to small sections of their forage area, such as rows 2 or 3 plants wide, to visually assess any response. Erect tropical forages such as Napier grass rapidly respond to improved nitrogen status by producing dark-green coloured foliage plus a more rapid growing, hence taller, plant. By applying different fertiliser regimes after each harvesting in trials (eg urea applied at 0 kg/ha, 50 kg/ha, 100 kg/ha, urea plus phosphorus fertiliser, with and without cow manure), farmers can assess how much urea they should be applying and whether they should be applying P as well as N. Because they can associate extra, darker green forage with more milk, in most cases they should respond accordingly by changing their fertiliser management.

8.2.4 Benefits of mixed swards

A mixed sward of grass and legume can provide high yields of forage with good energy and protein levels. However, the different growing habits of grasses and legumes makes it difficult to maintain the legume component of such a sward. The grasses recommended in Table 8.4 are all erect species whereas the few forage legumes in Table 8.4 are more prostrate. Following regular harvesting, the grasses would then quickly shade the legumes, thus reducing their growth rates. Furthermore, the two forages have different optimum harvesting frequencies. To maintain the longevity of the forage legumes, they should be sown as single species swards. Even then, weed infestation can be a problem.

Shading is less of a problem with tree legumes grown with grasses. The legumes are generally planted in an alley, or rows, and can easily be harvested at different intervals than the grass. The overall photosynthetic efficiency of the grass can be improved when grown in association with tree or shrub legumes, while during dry periods, the trees protect the grass from desiccation. Trees have deeper roots and the shade offers protection from the sun. A well-managed and fertilised grass and tree legume sward should produce the most productive and nutritionally balanced forage mix for milking cows.

One often mentioned example of integrated tropical fodder production is the three strata forage system in Bali, in which 0.25 ha of land is divided into a core, peripheral and circumference area (Nitis 1999). The core area is planted with the main food 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. Grass and ground legumes are harvested 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. The total yield of food crop is decreased by less than the reduction in area for cash crop, while forage production increases by 90% and is of higher protein content. Even though the system was developed for fattening beef cattle, it could also be incorporated into small holder cash crop or dairy systems.

8.2.5 Harvesting the crop

When harvesting forages, farmers tend to place too much emphasis on forage yield rather than forage quality. If forages are too mature and of poor quality, cows might produce less milk per hectare per year. In the wet season, there is always a compromise between harvesting high yields of low quality forages (7–8 MJ/kg DM of ME) and harvesting lower yields of higher quality forage (9–10 MJ/kg DM of ME). The data presented in Table 8.11 clearly show that Napier grass must be harvested frequently during the wet season (every 4 weeks) to produce a milking quality forage.

Table 8.11 Quality of Napier grass *(Pennisetum purpureum)* cut at various stages of regrowth during the wet season

DM, dry matter; ME, Metabolisable Energy; TDN, Total Digestible Nitrogen.

Regrowth (weeks)	Height (cm)	Crude protein (%)	ME (MJ/kg DM)	TDN (%)	Crude fibre (%)
4	50	10.8	9.6	62	28.5
6	75	8.8	8.1	54	32.2
8	135	8.0	7.9	53	32.8
10	150	7.8	7.7	52	33.0
12	150	4.6	7.5	51	31.9

In a recent review of published data on Napier grass, Muia *et al.* (2000) classified grass quality according to the crude protein (CP) requirements for various categories of milking cows. These were for cows at maintenance (5–7%) CP, or producing low (8–10%) CP, medium (11–13%) CP and high (14–16%) CP yields of milk. Predicted forage maturity, yield and nutritive value for these various swards are presented in Table 8.12.

High yielding cows then require Napier grass no more than 42 cm high and harvested every 30 days. Annual pasture DM yields are then likely to be only 60% of the Napier grass harvested for low yielding cows with annual yields of CP and ME being 105% and 73%, respectively. Therefore, although forage yields will suffer, milk yields will be less adversely affected.

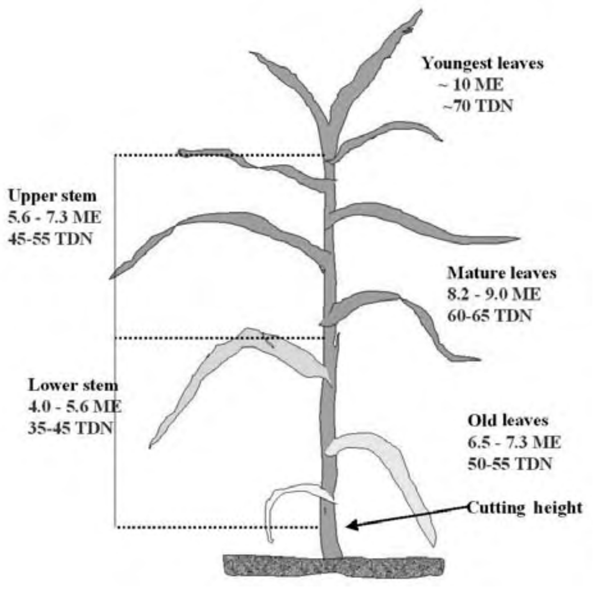


Figure 8.1 Variations in Metabolisable Energy (ME, MJ/kg DM) or Total Digestible Nutrients (TDN, %) of various plant parts of Napier grass (*Pennisetum purpureum*).

Table 8.12 Forage quality and yield of Napier grass *(Pennisetum purpureum)* cut at various protein contents crude protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). (Source Muia *et al.* 2000)

Forage protein content	5–7%	8–10%	11–13%	14–16%
Age (days)	99	63	53	30
Height (cm)	128	95	61	42
DM content (%)	20	17	16	14
NDF content (%)	68	63	61	54
ME content (MJ/kg DM)	7.1	7.7	8.3	8.9
Yield of DM (t/ha per yr)	28.5	21.8	19.7	13.7
Yield of CP (t/ha per yr)	1.7	2.0	2.4	2.1
Yield of ME (000 MJ/ha per yr)	202	168	164	122

The general recommendations for moderate milk yields (10–15 L/cow per day) in 450 kg dairy cows consuming 13.5 kg DM/d, is for Napier grass containing 8% to 13% protein and 7 to 8 MJ/kg DM ME. This can be supplied from forage harvested at 42 to 70 days, when 60 to 100 cm high, providing a carrying capacity is 4 to 4.5 cows/ha. For high daily milk production (<15 L/cow), harvest intervals would have to be decreased to 30 days. Milk yields per hectare would be high even with low carrying capacity, because of the increased protein yields. However, the increased cost of more frequent harvestings and greater fertiliser applications to maintain soil fertility will reduce the economic benefits of the higher milk yields.

Figure 8.1 shows the variation in nutritive value of various plant parts of Napier grass. This highlights the importance of only selecting the younger plants of better quality sections for feeding high yielding milking cows. Furthermore, the higher the leaf:stem ratio, the higher the nutritive value.

Harvesting tree legumes

With tree forages, regular harvesting of leaves is necessary to maintain favourable leaf to branch ratio. For example, *Leucaena* and *Gliricidia* should be harvested every 6 to 12 weeks. A 12-week harvest interval of *Gliricidia* can produce an annual yield of 9.2 t DM/ha when planted as a block or 1.1 t DM/ha (with forage containing 25% crude protein) when planted as a 40 cm fence around 1 ha of cropping land (Humphries 1999).

It is difficult to recommend specific harvesting regimes for all crops in every situation because the rate of forage growth depends on many factors, such as:

- forage variety – different varieties have differing optimum harvest intervals
- rainfall and/or irrigation
- soil fertility and additional fertiliser used
- harvest interval.

Wilting to improve forage intake

The high moisture content of young, freshly harvested forages limits the appetite of milking cows through high loads of water in the rumen (see Chapter 11). Wilting the forages for up to 24 hours removes intracell moisture without adversely affecting forage quality, provided the forage does not become heated. Data collected during the wet season in Indonesia are presented in Table 8.13. Conditioning is the process of physically damaging the stems, using pieces of wood, to fracture the epidermal layer and so aid the wilting process.

Table 8.13 The effect of wilting on the dry matter content of freshly harvested Napier grass (*Pennisetum purpureum*) and other forages at three sites in Indonesia

* Relative difference is difference in water extraction, expressed as percentage of that in the freshly harvested forage. Conditioning is the process of physically damaging the stems, using pieces of wood, to fracture the epidermal layer and so aid the wilting process. (Source: Moran and Mickan 2004)

Site	Plant part	Treatment	DM (%)	Difference	Relative difference in water extraction*
1	Leaves	Freshly harvested	25.3	5.2	7.0
1	Leaves	Wilted (26 hr)	30.5		
1	Stems	Freshly harvested	15.8	3.7	4.4
1	Stems	Conditioned and wilted (26 hr)	19.5		
2	Leaves	Freshly harvested	16.0	20.1	23.9
2	Leaves	Wilted (26 hr)	36.1		
2	Tops	Freshly harvested	11.5	13.9	15.8
2	Tops	Wilted (24 hr)	25.4		
2	Stems	Freshly harvested	9.0		
2	Whole plant	Conditioned and wilted	23.8		
2	Stubble	Rice straw	38.8		
2	Tops	Freshly harvested King grass	22.4		
3	Whole plant	Freshly harvested King grass	11.6, 10.4		
3	Whole plant	Freshly harvested Setaria	17.0		
3	Whole plant	Freshly harvested Glyricidia	25.9		

The degree of wilting differed markedly between Sites 1 and 2, in that wilting in Site 1 removed 4% to 7% of the original water in the freshly harvested forages whereas the longer duration of sunshine at Site 2 removed 16% to 24% of the original water.

The lowest dry matter content in any of the freshly harvested whole plants was in King grass, with only 10% to 11% DM. Clearly the dry matter intake of such material would be severely reduced unless the material was wilted prior to feeding.

9

Making quality silage

This chapter:

Explains the benefits of conserving excess forages as silage, the important principles of consistently making quality silage and how to calculate the size of the silage storage.

The main points in this chapter:

The 10 steps to making quality silage are:

- harvest the forage when excess to feed requirements and high in quality
- wilt the forage to 30% DM
- add a fermentable substrate at ensiling
- chop the forage into short lengths (1–3 cm) before ensiling
- compact the forage as tightly as possible
- complete the entire storage as quickly as possible
- seal storage air tight as soon as possible after filling
- maintain airtight seal until feeding out
- feed out a whole face of the storage to a depth of at least 20 cm each day
- if the silage is unsatisfactory, determine the reason for the next season.

Silage allows the long term storage of a variety of wet agro-industrial by-products.

Excess forages can be conserved as hay or silage. However, ensiling generally produces better quality roughage than hay because less time is required to wilt the feed, when the forage loses nutrients, causing a reduction in feed quality. Hay making requires a longer period of rain-free days, which are often rare in the tropics during the wet season when feed excesses generally occur. This manual will not discuss hay making.

The principles of silage making are the same regardless of size of operation, the major difference being in the type of storage used (Mickan 2003). However, the mechanics of silage making (labour, timing, resources) for individual small holders are completely different to those in larger communal farms, where labour and other resources can be shared or amalgamated for efficiencies of size of operation.

9.1 What is silage?

Silage is forage, crop residues or agricultural and industrial by-products preserved by acids, either artificially added or produced by natural preservation, in the absence of air. It must be emphasised that air is the biggest enemy of silage.

Ensiling is the preservation of a forage (or crop residue or by-product) based on a lactic acid (ideally) fermentation under anaerobic (no air) conditions. The lactic acid bacteria ferment the plant sugars (water soluble carbohydrates) in the crop to lactic acid, and to a lesser extent to acetic acid. The production of these acids reduces the pH (acidity) of the ensiled forage which inhibits spoilage microorganisms (due to their reduced activity). However, if ensiled under incorrect conditions, different and poorer quality fermentations can occur, producing other acids such as butyric acid, resulting in unpalatable and lower quality silages.

9.1.1 The four phases of silage making

Once the fresh material has been harvested, chopped, compacted and well sealed, the ensiling process then begins and undergoes four phases.

Phase 1 Aerobic phase

Any oxygen trapped between the forage particles is eliminated as a result of the respiration ('breathing') of the plant material and the aerobic (with air) activities of yeasts and bacteria. The plant enzymes are also active during this phase, provided the pH is still within the normal range for fresh material (pH 6.0–6.5). This phase may take a few hours only, provided the forage is well compacted and sealed as soon as possible after harvest.

Practical aspects of the aerobic phase:

- fill the storage site quickly (1–2 days)
- chop the material as short as possible (1–3 cm)
- compact the storage container as well as possible, as fingers should not be able to be inserted into the compacted forage
- seal the storage container air tight
- weight the top of the stack to maintain an airtight seal between the cover and compacted forage
- seal as soon as possible after harvesting is completed.

Phase 2 Fermentation phase

This stage begins once the oxygen is gone and the storage becomes anaerobic. Depending on the properties of the ensiled crop and the ensiling conditions, this phase may last several days to weeks. A successful fermentation will see the number of lactic acid-producing bacteria dominate, reducing the pH to 3.5 to 4.5. The lower pH level may be achieved in unwilted material whereas the higher levels are from wilted forages.

Practical aspects of the fermentation phase:

- mix molasses (at 3–5% on wet basis), a substrate source for the bacteria, to encourage lactic acid fermentation
- If possible, wilt forage to preferably about 30% Dry Matter (DM).

Phase 3 Stable phase

Once the pH level has dropped, and air and water is not permitted to enter the storage site, most microorganisms of phase 2 slowly decrease in numbers, resulting in a silage which is relatively stable. However, some acid tolerant microorganisms survive this period in an almost inactive state, along with others such as *Clostridia* and bacilli which survive as spores.

How to conduct the stable phase:

- Maintain an airtight seal around the silage
- Repair holes as soon as they are noticed.

Phase 4 Feed out phase or aerobic spoilage phase

This phase begins when holes are made in the storage site by mice, birdsor other agents or it becomes uncovered for feeding out. The aerobic spoilage phase occurs in two stages. Deterioration begins through degradation of the preserving organic acids by yeasts and occasionally acetic acid bacteria. This results in a rise in the pH and then the second stage of spoilage begins. This is associated with increasing temperature in the silage and activity by spoilage microorganisms such as bacilli, moulds and enterobacteria.

The rate of spoilage is highly dependent on the numbers and activity of the spoilage organisms in the silage and may be in the range of 1.5% to 4.5% DM loss/d.

Practical aspects of the aerobic spoilage phase:

- maintain an airtight seal
- feed out to ensure about 20 to 30 cm removal from the entire silage face each day
- if the silage gets hot, feed it out at a faster rate
- if silage heating occurs, consider a smaller stack face next harvest.

9.2 Why make silage?

All the major forages (grasses, forage legumes, tree legumes, by-product forages) can be stored as silage. Rice straw is sometimes mixed with very moist forages, to reduce effluent losses, but this results in a poorer quality silage. Rice straw could be used at the bottom of a silage pit, to absorb the highly polluting silage effluent.

Unfortunately tropical forages and legumes are not well suited to ensiling due to their inherent low concentrations of water soluble carbohydrates (ie sugar, or one of the storage carbohydrates mentioned in Chapter 4), compared to temperate species. However, rapidly wilting the forage or adding a fermentable substrate, such as molasses before ensiling, will usually result in well-fermented silages.

During the wet season, the tropical forage species grow very fast, with forage yields often exceeding animal requirements. If not cut and fed, it will continue to grow, producing very long and fibrous material, low in energy and protein.

If this forage was harvested and successfully stored as silage at the same stage as it is cut for producing milk, then it could be fed back during the following dry season. Although the quality of the forage will be slightly lower than its fresh state (10–15% lower in good ensiling conditions), it will still be better quality than many of the forages only available for dry season feeding. Conversely, in some locations, the silage can supplement other good quality but very slow-growing forages.

9.3 Silage storage systems

Silage can be stored in small plastic bags, 120 to 200 L plastic and steel drums (plastic lined or bagged), small or large pits dug into hillsides and in stacks above ground.

Steel and plastic drums should be stored on their lids to minimise losses if and when air enters the lid. When stored on their base, and air enters as it often will, then decomposition of the silage continues as more air enters. However, when stored upside down, the weight of the silage causes it to drop down inside the drum and minimise air entry.

The typical weights of silage in various types of storage or per unit volume in stacks are listed in Table 9.1. Weights will vary widely according to content of material, chop length, type of material ensiled and how well it was compacted.

Table 9.1 Weights of chopped silage in various types of storage

Storage type	Silage weight (kg fresh weight) or per unit volume
Small plastic bags, 30 × 30 cm	4–6
Medium size plastic bags, 105 × 85 cm	35–45
Small plastic drum (20 L)	15–20
Large plastic drums (120 L)	60–120
Steel drums (200 L)	140–190
Pits in ground	300–500 kg/m^3
Stacks above ground	200–400 kg/m^3
Cement boxes	200–400 kg/m^3

9.4 How much silage should be made?

The quantity of silage to store depends on several factors such as how many animals are to be fed, for how long, how much they are to be fed, the storage space available, the amount of excess feed to conserve, forage dry matter content, available labour and total costs. The following example shows the calculations for total silage requirements for a small holder dairy farm.

This farmer has four milking cows that must be fed for 90 days (3 months) on 20 kg/cow per day fresh silage, to supplement other forages and concentrate. If not wilted, 20 kg fresh material at 20% dry matter provides 4 kg silage DM/d.

To calculate total silage requirements:

4 cows × 20 kg/cow per day × 90 days = 7200 kg or a total of 7.2 t fresh weight required.

In most storage systems, there will be about 15% loss due to fermentation (this can be higher if air enters the storage). For a total of 7.2 t required, the fresh weight that needs to be stored is:

$$7200 \text{ kg} \div 0.85 = 8.5 \text{ t fresh weight.}$$

When compacted, pits or stacks contain say 300 kg/m^3 of fresh silage.

So the volume of storage is 8500 kg ÷ 300 kg/m^3 = 28 m^3.

If the stack is 1.5 m wide by 1.0 m high, then its length should be:

$$28 \text{ m}^3 \div (1.5 \text{ m} \times 1.0 \text{ m}) = 18.7 \text{ m long.}$$

This may be too long and the small holder would be better advised to have two pits each about 9 m long or three pits each 6 m long. More pits will also increase the flexibility of the storage system, for example if one pit is holed, if crops are of different ages or are different types.

If silage is to be fed at 80 kg/herd per day, and the whole feeding face is used each day at a minimum of 20 cm/d (0.2 m), the amount of silage removed each day would then be:

$$1.5 \text{ m} \times 1.0 \text{ m} \times 300 \text{ kg/m}^3 \times 0.2 \text{ m} = 90 \text{ kg}$$

(that is slightly more than the 80 kg silage required).

Therefore, to feed his four cows for three months, this farmer needs to source 8.5 t of fresh forage and store it in two or three pits each 1.5 m wide and totalling 19 m in length.

9.5 The ten steps to making silage

The success or failure in making quality silage is affected greatly by practices and requires a strict set of guidelines. There are no short cuts! Below are 10 steps to making good quality silage (Sections 9.5.1 to 9.5.10).

9.5.1 Harvest the forage

Forages should be harvested when excess to feed requirements but also when high in quality. In the wet season, tropical forages, such as Napier grass and sorghums, can grow rapidly to heights in excess of 2 to 3 m. Following this rapid growth, preferably even before it produces more forage than the small holder needs, this excess should be ensiled. This will allow the entire supply of forage to be maintained as high quality, into the dry season, rather than it becoming long with reduced leaf content, hence low in quality.

Forage harvested for silage should be at the same stage of maturity (ie its optimum), as if feeding fresh. For example, Napier grass should be harvested following 30 to 40 days regrowth in the wet season, at about 75 to 150 cm in height, for optimum quality and for ease of transporting to livestock in small holdings. At this stage, the Napier grass will have about two to three nodes showing on the stem.

Native roadside forages should be harvested when leafy and contain no prickly species. Tree legumes should be cut while leaves are still green and contain minimal twigs or branches.

9.5.2 Wilt the forage to 30% DM

Tropical species are difficult to ensile because of their high buffering ability (ie their resistance to changes in pH). To enable them to undergo a more satisfactory fermentation, two techniques are available to small holders, wilting the forage prior to and adding a fermentable substrate at ensiling.

Napier grass will be about 12% to 15% DM at harvest and should, if possible, be wilted to at least 30% DM. Wilting involves laying the cut forage on racks or against walls, to allow the sun's heat to evaporate some moisture from the plants. If rain is likely to fall, the material must then be covered (with plastic, palm leaves) or moved under shelter.

When harvested in the morning, wilting may only require the heat of the afternoon of that day, but when cut later in the day or on cloudy days, it may need wilting till midday of the following day. The layer of material to be wilted should be no thicker than 10 cm, and should be turned over two to three times to encourage wilting. If too thick, the forage will heat and begin to decompose and encourage the wrong types of bacteria to grow. Forage quality and dry matter will be lost.

Since leaves dry more quickly than stems, smashing or conditioning the nodes on the stems and the stems themselves will increase the wilting rate. Table 9.2 shows the effect of wilting on the final dry matter content of leaves and stems of Napier grass, as we measured in two locations in Indonesia.

Wilting Napier grass prior to making silage at workshops in West Java, Indonesia.

Table 9.2 Effect of wilting on the dry matter content (%) of leaves and stems of Napier grass (*Pennisetum purpureum*)
(Source: Moran and Mickan 2004)

	Fresh plant (at cutting)	Location 1 (after 24 h)	Location 2 (after 28 h)
Leaves	22	27	46
Stems	10	12	17

In these two locations, native roadside forages, harvested at 15% DM in the early morning was wilted to 29% DM after 4 hours and to 37% DM after 26 hours.

The dry matter content of forage can be assessed as follows:

1 cut a representative sample (including leaf and stem) into 1 to 2 cm lengths
2 squeeze tightly in hand for 30 to 60 seconds
3 open the hand quickly and observe the material and amount of moisture.

It will be approximately 30% DM if:

- your palm becomes moist but not wet
- no water drips from your hand
- the squeezed forage does not spring quickly back to its original form.

9.5.3 Add a fermentable substrate at ensiling

If the fresh forage cannot be wilted, the fermentation of the silage will be improved by mixing the chopped material with 3% to 5% molasses (on a fresh weight basis) just prior to ensiling. Although this is a time consuming and messy job, the rewards are well worth it. Adding water to the molasses is not recommended as the forage is already too moist and extra water will just reduce the fermentation quality.

Rather than mixing it in thoroughly, the molasses can be spread as layers in the forage, say every 10 to 15 cm. Where the molasses is applied, the silage ferments better and is sweeter smelling, but the overall silage quality is still good. Other suitable fermentable substrates include rice bran or formulated concentrates (mixed at 10%) in layers with molasses (5%) poured on top of the rice bran. We found the silage surrounding the rice bran was drier and more acidic (pH 4.1) compared to silage with no additive (pH 4.5).

9.5.4 Chop the forage into short lengths

The shorter the chop length, the better the compaction, hence less air is trapped in the forage, resulting in better silage quality. Chop lengths should be from 1 to 3 cm. Mechanised forage choppers will chop quickly to very short lengths. However, small holders can manually achieve similar chop lengths using knives but at a high labour input and more slowly.

If chop lengths are longer, additional molasses (5–6% on a fresh forage basis) may improve the fermentation. However, the stems should be chopped to small lengths because they are harder to compact. Leaves can be left at 3 to 8 cm length.

Where the forage has become too long but is still in a vegetative state (not yet in head), only chop and ensile the leaves and the top end of the stems to produce a higher quality silage.

9.5.5 Compact the forage as tightly as possible

Regardless of the system of silage storage, the forage must be compacted as densely as possible, so compact it until it is difficult to insert your fingers into the stack. The shorter the material is chopped, the more dense it can be packed and the less air that will be trapped inside the stack.

If compaction is by human trampling, be wary of trapping pockets of air inside the stack. The edges of the storage must be well packed. Poles or feet may be used to compress the edges in drums and material must be pushed into corners of plastic bags by hand. Be careful not to puncture the plastic bags with fingers, wooden poles or any other implement.

Larger stacks of silage in cement boxes or in pits in the ground will require continual trampling while the forage is being delivered. It should be spread evenly and thinly (no more than 5–7 cm thick) over the stack to enable it to pack more densely.

9.5.6 Complete the entire storage quickly

The entire silage storage should be filled and sealed in one day, and at a maximum, two days. This is easily achieved with bags, drums and small concrete boxes.

In larger stacks, where the forage may require several days to be delivered, the forage from one day should cover that from the previous day to a depth of at least 1 m. The current day's forage then acts as a 'seal' for the previous day. If some of the previous day's forage is not covered sufficiently, it will suffer from aerobic deterioration causing the stack to heat up, with subsequent losses in both quantity and quality.

Each night until it is filled, the stack should be covered with a sheet of plastic or a thick layer of banana or palm leaves. This will minimise the amount of warm air leaving the stack, which sets up convection currents, thus encouraging more air to enter. This is particularly important with wilted tropical forage, as it is more prone to aerobic deterioration than are temperate forage species.

9.5.7 Seal storage air tight

Silages in well-sealed storages that prevent the entry of air or water will maintain their quality for much longer than will silage in poorly sealed storages.

Plastic bags: Forages ensiled inside small bags should be stored inside a second bag as the thin plastic is easily punctured. Furthermore, non-punctured stretched plastic can allow entry of air. To ensure a tight seal, the neck should be twisted and then tied or taped, then doubled over and retied or retaped.

Forage maize ensiled in large plastic bags in Guizhou province, China.

Bags must be stored under cover and protected from any animal (eg vermin, rodents, birds, poultry), children or other agents which may cause punctures. They should also be protected from direct sunlight, to prevent the plastic breaking down, and to minimise direct heating of the bags.

Plastic and steel drums: The tops of the drums should be covered with a sheet of plastic before the lid is placed on top. To ensure an airtight seal once clamped or screwed in place, plastic tape should be placed around the top. The drums should then be stored upside down, preferably under cover or protected from direct sunlight to minimise heating.

Concrete silo or boxes: To reduce losses through aerobic deterioration once opened, it is useful to divide large concrete silos into smaller compartments. This can be done with straw, mud, cement bricks or using a rectangular timber frame. At least one side of the stack should be sealed with plastic, to prevent air entry during feed out (Figure 9.1). Straw placed above stones in the base of the pit allows moisture to seep to the bottom, but does not allow air entry into the stack. The stones should be about 2 to 4 cm high depending on stack size.

The box in Figure 9.1 holds 24 m^3 of silage, too much to open and possibly expose to the air, all at the one time.

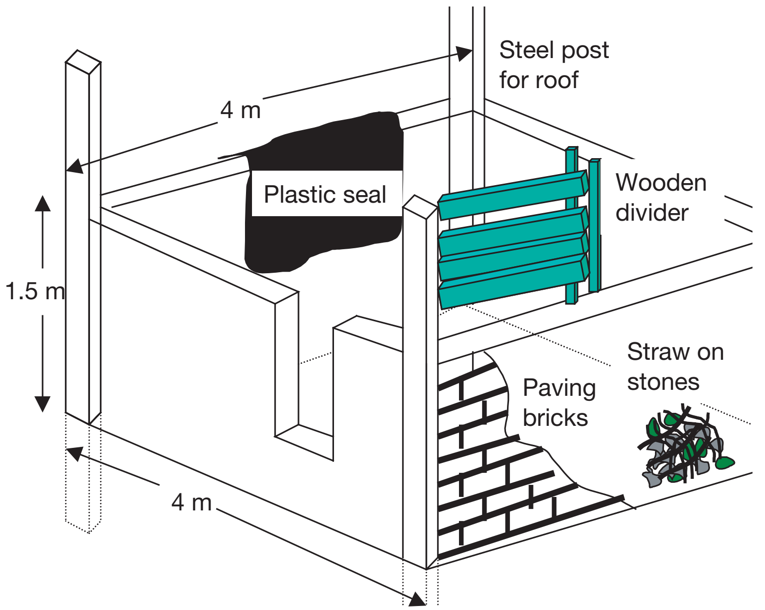


Figure 9.1 Concrete silo or box with a wooden divider.

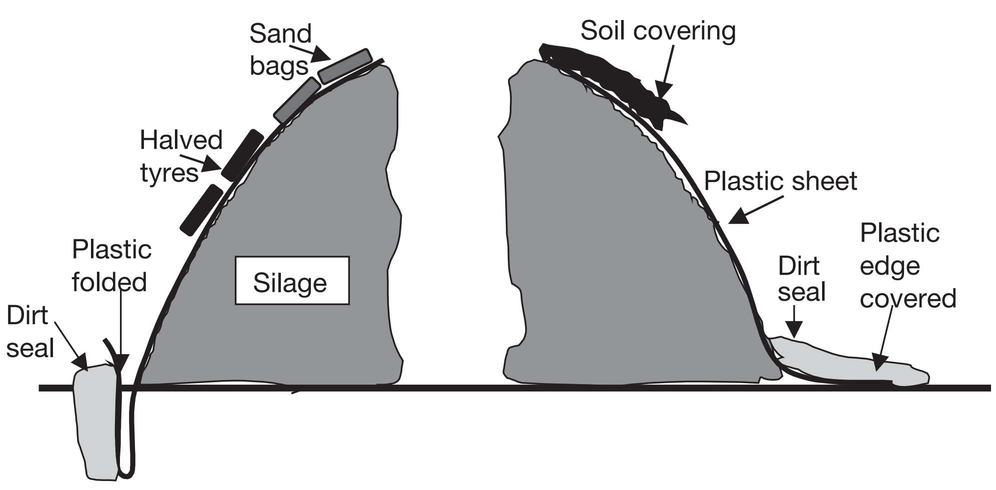


Figure 9.2 Stacks of silage showing sealing techniques at edges and on top.

Silage pits or bunkers: Immediately the filling is complete and the stack well compacted, it should be sealed air tight using plastic, preferably plastic treated with a ultraviolet (UV) light inhibitor. If such plastic is not available (eg if only builder's plastic is available), it should be entirely covered with about 10 to 15 cm of soil to protect it from direct sunlight.

When using UV treated plastic, it must be weighted with tyres cut in half or sand/dirt-filled bags, to maintain the plastic close to the silage, preventing air entry and movement under the seal. Covering the plastic with soil would be ideal. The plastic edges, when folded over then buried, as shown in Figure 9.2, provide an excellent airtight seal.

9.5.8 Maintain airtight seal

All storage types must be sealed then kept air tight throughout the entire storage. If the plastic is holed, or stacks start to shrink too much, the cause of air entry into the silage must be determined and repaired as soon as possible.

Effluent flowing out of the storage for longer than 2 to 4 weeks is indicative that the silage is slowly deteriorating (rotting) due to entry of air. The air entry should be identified and stopped. If it cannot be stopped, ensure that the same mistake is not made in the future. (A mistake is something wrong that happens more than once!)

Wilted silage should produce little or no effluent unless the stack is poorly sealed. Unwilted silage will produce some effluent, which may leak out of drums and stacks into the soil. Silage effluent should be prevented from entering waterways and drinking water as it causes pollution. It can kill plants or fish if in large quantities.

Only small amounts of silage effluent will leak from well-sealed drums and plastic bags, and may even leak slowly from upturned drums. It is important not to remove drum lids, untie bag tops or hole their bottoms to let moisture out, or to 'see how they are going!' This will allow far too much air to enter, leading to very poorly fermented silages, and even just compost.

9.5.9 Feed out a whole face of the storage

As soon as the storage is opened for feeding, air will enter and the silage will begin to deteriorate. Silage in small storages should be fed out completely within 1 to 3 days of opening. If drums are being fed out over longer than three days, plastic and weights should be placed over the open face to minimise air entry to the silage.

Unless the forage has been chopped very short (1–3 cm) and well compacted, air enters silage stacks of tropical species very easily. For large silage storages, the whole face of the stack should be removed every day to a depth of at least 20 cm. If the silage is fed out only every two days, at least 30 to 40 cm should be removed every second day. Stack widths should be designed to ensure it takes no longer than two or three days to feed out the entire feeding face.

Only remove the weighting material on top of the stack as required to prevent air moving back into the stack under the top seal. If the silage is warming once opened, it is starting to deteriorate and lose yield and quality. If steam is rising from the stack or if the silage becomes very hot, aerobic deterioration is extreme and the feeding rate must be increased rapidly, unless the problem is due to air entry via other means.

9.5.10 If silage is unsatisfactory, determine the reason

It is important to learn from mistakes and to ensure that the silage is consistently of good quality from year to year.

Silage that has undergone an unsatisfactory fermentation will be unpalatable, and in some cases even poisonous to animals. Once opened, such silage may be recognised by the following characteristics, as it:

- has a strong, pungent, very unpleasant smell
- has a strong ammonia smell
- contains excess moisture when squeezed or continually oozes from the base
- is mouldy or slimy
- has undergone much deterioration (>20% DM loss)
- is slightly damp and dark brown
- the plastic sheet or lid has not stopped air entry for many days.

Even though animals may not eat the silage initially, they should once the silage has been left in feed troughs for an hour or so, thus allowing some of the pungent smells to escape. However, animal production will suffer as a result. To avoid any possible animal health problems, be very wary of feeding mouldy silage to pregnant and lactating animals.

Silage has a characteristic odour unfamiliar to most livestock. Therefore, they may not immediately consume the silage offered without some incentive, such as molasses or fresh forage mixed in with the material. It is very unusual for stock to refuse silage after a slow introductory period.

Even when they make good quality silages, farmer adoption rates of silage making have not always been high. As with other feeding technologies such as chemically treated rice straw, farmers do not like to double handle forages. Often, they need to see the benefits of feeding better quality roughages in higher milk yields, before they accept the higher work loads in silage making compared to purchasing other forages, generally of poor quality, for dry season feeding. Another problem is the shortage of excess wet season forage with which to make silage because of high stock numbers on limited areas.

9.6 Silage from by-products

Fruit, fish waste, vegetables and root crops are increasingly integrated into tropical farming systems and provide a wide range of valuable wet by-products and residues which are often underutilised or wasted. The ensiling of such by-products is a simple conservation method and a most effective way to improve animal feed resources.

The major problems usually encountered are the seasonality of supply and their high moisture content. High moisture by-products often have high nutritive value. It is difficult and expensive to dry them so all too frequently such by-products often become contaminating wastes that quickly go sour, mouldy and lose much of their soluble nutrients as effluent. The advantages of ensiling such material include:

- for feeding when such by-products are not being produced
- increasing feed resources and an insurance for high nutrient demands, such as milking cows

- reducing demands on homegrown forages
- if low cost, reducing total feed costs
- can improve their palatability
- can reduce toxicity to safe levels (in vegetables or cassava leaves)
- can destroy harmful bacteria (in poultry litter or fish wastes)
- can constitute a major proportion of diets.

9.6.1 Sources of by-products

There are a wide variety of wet by-products or residues and their nutritive values are presented in Table 9.3. This list does not include cereal by-products (rice bran) or drier by-products (coconut meal) which can be stored fresh. These are discussed in Chapter 10.

Brewer's spent grains: The extracted malt or spent grain contains 75 to 80% water and can be stored under cover for up to 2 weeks. It needs airtight storage for longer periods, either in trenches or large plastic bags. Including other by-products such as molasses or chopped cassava provides additional carbohydrates for improved fermentation while absorbing some of the moisture.

Banana by-products: These include reject bananas, leaves and trunks. Mixing bananas with high protein wastes such as poultry litter, fish waste or cassava leaves, produces a high quality milking feed. Banana trunks, although poor quality, produce good quality silage when ensiled with high carbohydrate feeds such as molasses or root vegetables.

Root crops: These include cassava, taro, sweet potato and yams. Cassava roots are a high energy, but low protein feed, ideal for high yielding cows (up to 25% of their total DM intake) provided they are supplemented with additional protein and minerals. Fresh cassava leaves are also a good quality forage for cows provided they are ensiled or sun dried to remove the toxic hydrocyanic acid they contain. Taro and yam roots contain unpalatable substances that are reduced by ensiling.

Wet pulps from fruit and vegetables: Citrus pulp represents 50% of weight of the fruit prior to juice extraction. Tomato pulp (peel, seeds) constitutes 20% of the fresh weight. Being so moist, they should be ensiled in alternative layers with dry by-products, such as chopped straw, cereal bran or poultry litter, to absorb the effluent. Sweet corn waste is a high energy by-product because of the large amounts of soluble sugars remaining following canning of sweet corn. Grape marc constitutes 5% to 10% of fresh grapes but is low in nutritive value because tannins reduce the availability of other nutrients, particularly the protein.

Miscellaneous: Fish by-products are very high quality protein sources for lactating cattle, because being animal in origin, their amino acid profiles are the most similar to those required by rumen microbes and cows themselves. They should be ensiled in association with high carbohydrate feeds (eg molasses or cassava roots) with maximum amounts of 50% with dry sources and only 10% with other wet by-products.

Poultry litter and manure is also rich in protein and minerals and can be incorporated into cow diets either as a dried or ensiled product, with the latter method destroying harmful microorganisms, such as *Salmonella*. Cassava and soybean wastes are readily available in many areas for 12 months each year so can be fed fresh.

Other less common by-products available in some tropical regions include condensed molasses fermentation solubles, the organic residues of microbial fermentation to produce monosodium glutamate and fermented soybean paste residue, produced after soy sauce has been extracted from soybean paste under pressure. Many Asian countries have by-products from medicinal herbs, such as ginseng, which may have potential for feeding to livestock. However, before using them, it would be advisable to obtain a full chemical profile of such residues to ensure they have no detrimental effect on cow performance or milk quality.

Table 9.3 Nutritive value of tropical by-products suitable for ensiling and inclusion rate for feeding to milking cows

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME). (Source: Chedly and Lee 2000)

By-product	DM (%)	CP (%)	CF (%)	ME (MJ/kg DM)	ME (MJ kg fresh)	Inclusion rate (kg fresh/d)
Fruits						
Reject bananas	30	5.4	2.2	11.5	3.5	2–5
Banana skins	15	4.2	7.7	6.7	1.0	2–5
Bread fruit (ripe)	30	5.7	4.9	10.8	3.2	4–8
Tomato pulp	22	21.5	35.0	8.0	1.8	1–15
Sweet corn waste	18	2.6	21.0	11.0	2.0	1–10
Grape marc	37	13.8	41.0	4.9	1.8	1–3
Citrus pulp	23	7.5	20.0	10.3	2.4	1–15
Leaves and stems						
Banana stems	9	2.0	21.0	5.5	0.5	5–10
Sweet potato leaves	12	20.0	14.5	5.8	0.7	10–20
Cassava leaves	16	23.5	19.0	6.7	1.1	3–6
Taro leaves	16	22.3	11.4	6.2	1.0	1–2
Maize stover	23	5.7	26.4	8.7	2.0	5–20
Yam leaves	24	12.0	25.0	7.3	1.8	2–5
Roots						
Cassava roots	28	1.6	5.2	12.5	3.6	5–15
Taro roots	25	4.5	2.0	13.2	3.3	2–5
Yam roots	34	8.0	2.5	13.5	4.6	2–5
Sweet potato tubers	30	7.0	2.5	13.5	4.1	5–10
Sugar beet pulp	19	9.1	31.6	9.8	1.9	1–20
Miscellaneous						
Poultry litter	82	26.5	14.5	8.2	6.7	0.5–2
Cassava waste	20	2.5	1.5	7.2	1.4	1–10
Soybean curd	14	39.0	11.3	14.9	2.1	1–5
Brewer's grain	22	26.0	13	8.2	1.8	5–20
Molasses	78	1.5	0	11.5	9.0	0.5–2

9.6.2 Principles of ensiling by-products

The basic principles are the same as those for fresh forages, so attention must be paid to ensuring anaerobic conditions and there should be sufficient acid in the silage to restrict the activities of undesirable bacteria. To achieve a successful silage, attention should be given to:

- Moisture content – this should be at least 50% for ease of compacting to eliminate air. Excessive moisture, more than 75%, can lead to an undesirable fermentation, producing a sour silage reducing palatability and hence intake. Adding water or using absorbent materials will allow the manipulation of moisture content.
- Length of chopping – the finer the chopping, the better the compaction.
- Time to fill the stack – the quicker the better, and it should be covered each night during filling to reduce invasion of air.
- Fermentable energy – these silages require a stable low pH to minimise biological activity. The final pH depends on the carbohydrate content, which may be sufficient in the material being ensiled or from added sources. For example, protein-rich by-products with low sugar or starch contents are difficult to ensile so should be mixed with energy-rich by-products such as waste bananas, molasses or root crops.
- Once opened, every effort must be made to reduce aerobic deterioration. Ensiling in layers separated by plastic sheets can reduce the size of each package of silage. Plastic bags are easy to handle as well as making excellent mini silos.
- Well-made silage can be opened within one month or can be stored for six months or more, provided the cover does not break down and allow air to enter the stack.

Workshops allow small holder farmers to quickly understand the benefits of silage in conserving excess forages.

9.6.3 Silage from maize crops and maize by-products

Maize is probably one of the most versatile of all crops. Many varieties of maize have been bred, differing in their rate of maturing, to produce a diversity of crops for different end products, such as sweet corn, forage maize and maize grain (Moran 2001b). The types of maize and by-products used for livestock feeding are:

- Sweet corn, which is consumed fresh either directly off the cob or already removed from the cob or preserved as frozen or canned sweet corn.
- High moisture maize and ground ear maize, which are both wet products from maize harvesting, the first being grain only and the second a mixture of grain and cobs.
- Maize stover, which is the leaves and stems of maize plants following its harvest for sweet corn. The stover remaining from crops grown for maize grain is very poor in quality because of its mature stage at harvest.
- Maize grain and its many by-products (see Chapter 10).
- Sweet corn trash, which is the by-product from canned sweet corn, namely cobs, leaves around the cob and some of the soluble maize from the kernels.
- Whole crop forage maize, which is the entire crop harvested in a less mature stage than when harvested for grain. It is fed as green chop or is more commonly ensiled for later feeding.

Farmers can utilise this theoretical knowledge and construct silage pits on their own farm.

Most of the forage maize harvested, and often ensiled, for small holder dairy farming is maize stover, although some farmers grow or purchase whole crop forage maize. Nutritive values of these feeds are presented in Tables 9.3, 10.2 and 10.4.

10

Supplements for milking cows

This chapter:

Explains how to select a supplement based on its nutrient composition.

The main points in this chapter:

- factors to consider when deciding on which supplements to use:
  - what is the limiting nutrient in the diet?
  - which supplements are available and what is their nutrient composition?
  - what are the practical considerations of feeding?
  - how will a supplement affect the balance of the diet?
- feeds can be classified as energy supplements, protein supplements, basal forages and forage supplements
- tables of feed composition show the wide variation in energy and protein content in feeds
- chemical treatment of low quality roughages can improve their nutritive value but unsupplemented, they will not support high milk yields.

It is unlikely that the entire diet of milking cows will consist of just one forage. These other feeds are called supplements to the major forage source. If there is no major forage source, all feeds could be considered as supplements. This chapter addresses some practical and nutritional considerations involved in the use of different supplements.

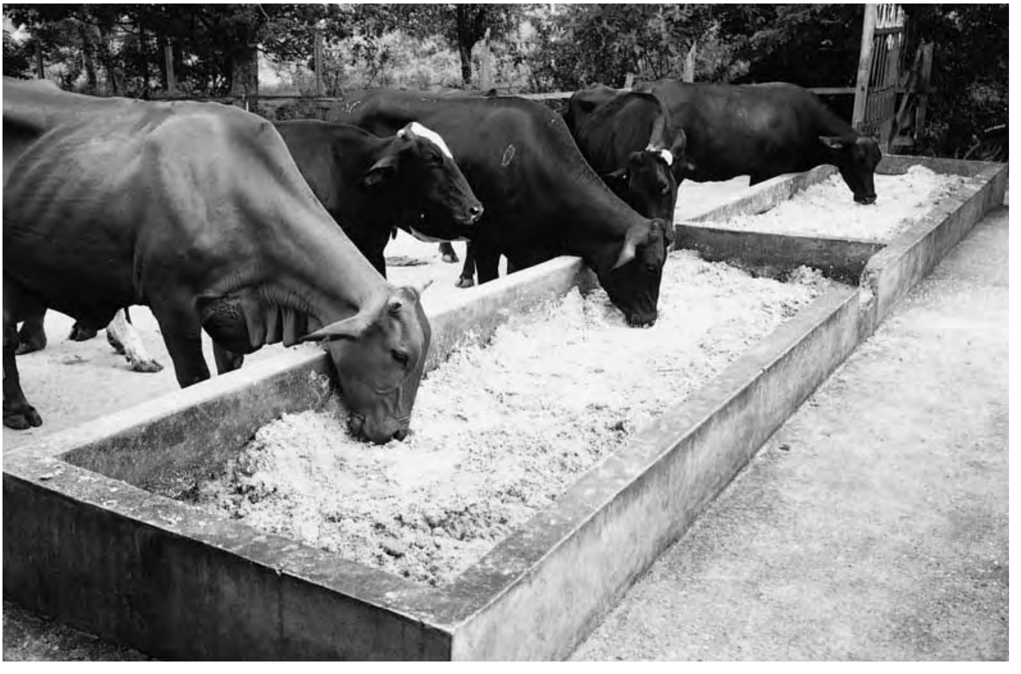
10.1 Choice of supplement

Several supplement types are fed to dairy cattle. The decision on which supplement is determined by a combination of factors, such as:

- What is the limiting nutrient: energy, protein, fibre or a combination of all three?
- What supplements are available?

- What is their nutritive composition?
- What are the relative costs?
- What are the practical implications (eg facilities for storage and feeding, labour requirements, reliability of supply?)
- What are the nutritional implications: how will the supplement affect the ration balance, and could problems such as acidosis arise?

In forage-based dairy systems, energy is normally the first limiting nutrient. Therefore, supplements should be compared on the basis of their cost per unit energy, such as Thai baht per kg of Total Digestible Nutrients (TDN) (as in Table 8.1) or Vietnam dong per MJ of Metabolisable Energy (ME) (as in Table 8.2). The lower the cost of energy supplied, the cheaper the supplement. Supplements can also be compared on the basis of cost per kilogram of Crude Protein (CP) supplied.



Malaysian milking cows in Malacca eating fresh citrus pulp.

10.1.1 Defining the nutritive value of supplements

Supplements are classified by their ability to supply additional energy, protein, fibre or vitamins and minerals to dairy cows. They come in the form of concentrates, fresh forages, conserved fodder, roughage by-products and concentrate by-products.

Most tables of feed composition report only the average energy and protein contents. Yet, there can be large variations within any type. For example, plant-derived feeds may vary with season of growth, soil type and crop management.

To categorise South-East Asian feeds on their composition, data from analyses of local feeds in Thailand (Wanapat and Wachirapagoin 1990) and Indonesia (J Moran, unpublished 2003) are presented in Tables 10.2 to 10.5 and summarised in Table 10.6.

The tables list the actual values for Dry Matter (DM%), energy (Metabolisable Energy, and Total Digestible Nutrients), Crude Protein (CP%) and fibre, usually Crude Fibre (CF%) but occasionally Neutral Detergent Fibre (NDF%). Such values are necessary to calculate ration formulations (see Chapter 12) but also to represent 'typical' nutritive values of these particular feed types. Other chemical analyses of the same feed type can differ considerably to those in these tables. This highlights the importance of analyses of the actual feed ingredients used for the most accurate formulation of that ration.

10.1.2 Degradability of supplement protein

Tables 10.2 to 10.5 also present the supply of Undegradable Dietary Protein (UDP) and hence Rumen Degradable Protein (RDP) according to categories listed in Table 10.1. These data are collected from worldwide information by Target 10 (1999).

The more processed the supplement, the greater its degree of protection from rumen degradation of protein. Highly processed protein meals such as fish and blood meal are excellent sources of undegradable dietary protein, hence are in the high category. Most other protein meals are moderate sources of Undegradable Dietary Protein. Maize, sorghum and rice are also in the medium category, whereas other cereal grains fed in temperate countries, such as wheat, triticale and barley, are poor suppliers of Undegradable Dietary Protein. Formulated concentrates can be moderate when pelleted or poor when fed as meals. Forages conserved as hay are moderate sources but only poor suppliers of Undegradable Dietary Protein when fresh or ensiled.

Table 10.1 Categories used to describe supplements on their ability to supply protein as Undegraded Dietary Protein (UDP) and Rumen Degradable Protein (RDP)
Rumen Degradable Protein (RDP); Undegradable Dietary Protein (UDP). (Source: Target 10 1999)

Category	UDP	RDP
High (H)	> 69%	< 31%
Good (G)	50–69%	31–50%
Moderate (M)	30–49%	51–70%
Poor (P)	10–29%	71–90%

The tables in the following sections in this chapter cover energy and protein supplements, fresh and conserved forages and forage by-products presenting the nutritive value of each feed type.

10.2 Energy supplements

10.2.1 Types of energy supplements

Feeds with large quantities of starches and sugars (eg cereal grains and some by-product feeds) are good energy supplements. Maize, sorghum and rice are cereal grains, while cassava and sweet potatoes are root crops. Many farmers feed commercially formulated concentrates and frequently high-energy by-products such as rice bran, cassava waste and brewer's grain. Analyses of some energy-rich supplements are presented in Table 10.2. The formulated concentrates are from Thailand. The protein content of formulated concentrates varied considerably but there was little difference in the energy values of the three concentrates in Table 10.2.

Cassava roots and molasses are very low in protein (2–4%), while much of the energy in cassava can be extracted during processing. For example, the Metabolisable Energy content of Cassava waste 1 decreased from 12.9 (for cassava chips) to only 7.2 MJ/kg DM. However, with other cassava waste (Dried cassava waste 2) the Metabolisable Energy can still be relatively high (12.6 MJ/kg DM). As a result of contamination with rice hulls, the nutritive value of rice bran varies considerably with grade. These two examples from Table 10.2 highlight the problems of making generalities of the nutritive value of crop by-products. The nutritive value of a range of wet by-products has been presented in Table 9.3.

Table 10.2 Nutritive value of some common energy-rich supplements available in South-East Asia

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). See Table 10.1 for details of UDP supply: moderate (M); poor (P). (Sources: Wanapat and Wachirapagoin 1990 and J Moran, unpublished 2003).

Feed	DM (%)	CP (%)	CF (or NDF) (%)	ME (MJ/kg DM)	TDN (%)	UDP supply
Cassava chips	88	2.1	3.4	12.9	80	M
Maize grain	85	11.0	(9.0)	13.5	83	M
Sorghum grain	90	12.0	2.5	14.6	89	M
Paddy rice	89	8.9	10.1	12.7	79	M
Brown rice	88	10.3	1.2	15.1	92	M
Molasses	79	2.8	-	14.0	86	P
Rice bran 1	91	14.1	12.8	11.1	70	M
Rice bran 2	89	7.7	26.1	7.9	53	M
Sweet potatoes	32	5.0	5.9	12.9	80	P
Dried pineapple waste	85	4.6	22.7	11.1	70	M
Cassava waste 1	20	2.5	1.5	7.2	49	P
Dried cassava waste 2	88	1.9	(22.2)	12.6	78	M
Sweet corn waste	18	12.6	21	11.0	70	P
Wheat pollard	89	15.0	(36.6)	12.5	78	P
Brewer's grain	26	28.8	(57.0)	10.2	65	M
Concentrate 1	90	17.2	(26.5)	11.2	71	P/M
Concentrate 2	90	19.3	(25.8)	11.4	72	P/M
Concentrate 3	90	19.9	(25.1)	11.2	71	P/M

10.2.2 Milk responses to energy supplements

Milk responses should be expressed as the extra milk produced per additional kg DM of the supplement fed (L milk/kg supplement DM), that is the marginal response to supplement feeding. Milk responses to supplementary feeding vary widely, depending on stage of lactation, quality of supplement and amount of forage consumed (see Chapter 11 for detail).

Stage of lactation

With energy supplements, responses can be over 1 L milk/kg DM of supplement fed in early lactation while this decreases in late lactation. This is because cows partition more dietary energy into regaining body condition during late lactation, hence less is expressed as extra milk.

Forage and supplement quality

Trials with grazing cows have shown consistently that milk responses vary with forage quality, with better milk yields being on lower quality pastures. This would also occur with cut and carry systems, when forage supplies are adequate. However, in most cases, small holder farmers do not fully feed their cows on fresh forage so the quality of that forage is less likely to influence the milk response to the energy supplement. Milk response per kg DM of energy supplement generally increases with supplement quality.

Formulated concentrates would be expected to yield better milk responses than high energy cereal grains and by-products, because they would be formulated to supply extra protein, minerals and vitamins. However, research has consistently shown that milk responses in cows fed cereal grains are equivalent to those of formulated concentrates, up to 5 kg/cow per day.

Farmers in developed countries often feed fat supplements to provide additional energy. These can take the form of either cooking oils or tallow (from slaughter houses), while some fats have been specially processed to bypass rumen digestion. Fats that are present in the rumen may coat fibre in the diet, and can reduce fibre digestion if dietary levels are too high. The upper limit for dietary fat concentration is about 5% of total DM. Many countries have banned the feeding of ruminant-based feeds, such as tallow, because of concerns with 'mad cow disease' (bovine spongiform encephalopathy), which originated from this practice.

Bypass fats are digested in the small intestine and can be fed at higher levels without these side effects. However, they are very expensive, up to A$950/t. They should only be fed during early lactation to high yielding cows (producing greater than 30 L/day).

Feeding high levels of high starch feeds or suddenly increasing their amount in the diet can lead to acidosis. This is caused by a build-up of lactic acid in the rumen. Increased acidity reduces the activity of the microbes that break down fibre, which results in slower digestion and reduced appetite (see Chapter 13 for further details).

10.3 Protein supplements

The nutritive values of some common protein-rich supplements available in South-East Asia are presented in Table 10.3. Many of these are derived from by-products of leguminous grains, such as peanuts, soybean and sunflowers, while others are whole grains, such as mung beans and cottonseed.

Urea is a common source of nitrogen, but being a form of non-protein nitrogen, it is not a true protein. It has no energy value and is all degradable in the rumen. It is sometimes used as a substitute for true protein sources in feed mixtures and pellets, but is only effective when fed in combination with an energy source such as cereal grains or maize silage. It is recommended that urea only be fed to animals that have a fully functioning rumen and at a maximum rate of 1% of total DM intake.

The highest quality protein supplements originate from animals (eg fish, shrimp, blood). This is because much of their protein escapes rumen degradation and is more efficiently digested in the intestines. These supplements, originating from animals, have amino acid profiles more closely related to those in milking cows, hence are more efficiently utilised following digestion. The feeding of meat and bone meal, once considered an excellent protein supplement, has been banned because of mad cow disease. Energy levels of these protein meals, with the exception of shrimp waste, are comparable to those of cereal grains.

Table 10.3 Nutritive value of some common protein-rich supplements available in South-East Asia

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). See Table 10.1 for details of UDP supply: high (H); good (G); moderate (M); poor (P) (Sources: Wanapat and Wachirapagoin 1990 and J Moran, unpublished 2003)

Feed	DM (%)	CP (%)	CF (or NDF) (%)	ME (MJ/ kg DM)	TDN (%)	UDP supply
Soybean meal	91	48.7	6.2	14.0	86	M
Coconut meal	92	19.2	(49.3)	12.0	75	M
Peanut meal	93	50.6	16.0	13.6	84	M
Mung beans	91	28.3	5.7	14.0	86	P
Sunflower meal	94	52.4	5.7	12.0	75	M
Cottonseed meal	93	44.3	12.8	12.5	78	M
Whole cottonseed	92	30.3	23.1	9.8	63	M
Palm kernel cake	91	15.1	66.4	12.1	76	M
Kapok seed	86	27.4	28.0	10.3	66	M
Fish meal A	90	64.7	0.7	10.5	67	H
Fish meal B	94	59.8	2.2	11.6	73	H
Blood meal	92	89.7	0.9	10.3	66	H
Shrimp waste	90	52.0	12.3	7.0	48	G
Soybean curd	15	22.2	(30.2)	13.3	82	M
Urea	100	280	–	–	–	–

Good milk responses to protein supplements can only be obtained if they are used to overcome an actual protein deficiency. Otherwise, they are broken down and used inefficiently as an expensive energy supplement.

10.4 Basal forages and forage supplements

The nutritive values of common forages and forage supplements found in South-East Asia are presented in Tables 10.4 and 10.5. The supplements are generally the poorer quality forages, those that are fed as a last resort when better quality forages are in short supply.

There are many species of grasses sown for small holder dairy systems (see Chapter 8), and Table 10.4 lists 'typical' values for well-managed grass swards. Forage quality varies with many factors that include:

- grass species
- stage of plant maturity
- environment (rainfall, temperature, sunlight)
- soil fertility
- fertiliser regime
- mixed swards (eg growing grasses in combination with legumes).

The high growth rates of tropical grasses are associated with greater stem development and hence lower leaf to stem ratios than in temperate grass species. Stems contain more fibre and less energy and protein than leaves, hence tropical grasses have the lower nutritive values.

As such forages approach the end of the vegetative stage of maturity, and become reproductive, flowers and seeds develop in the grass heads and their nutritive values decline. Plant fibre levels increase and energy decreases. Therefore, it is essential to maintain the vegetative stage of maturity in grasses to ensure quality forage, particularly for milking cows.

Fertilisers not only promote rapid growth but also improve forage quality, both protein and energy levels (see Chapter 8). Cow manure does not provide sufficient nutrients to promote maximum growth and optimum forage quality.

Energy and protein levels in well-managed tropical grasses are only moderate, ranging from 7 to 9 MJ/kg DM of ME and 6% to 12% protein (Table 10.4). Legumes have higher protein, and often higher energy values than grasses. The best quality, and often highest yielding, grass species is maize, with whole crop maize usually fed fresh or conserved as silage. Maize silage should be harvested at the correct stage of maturity to achieve maximum dry matter yield and quality. This is because the grain that develops in the cob compensates for increasing fibre levels in the stalk and leaves. The low protein content of maize silage means additional protein supplements are needed when fed in large quantities.

Many of the by-product forages in Table 10.4 have reasonable energy and protein levels but they are not readily available throughout the year and are only found in certain regions. Therefore, they may be the major source (hence basal forage) for only short periods of the year.

The forage supplements included in Table 10.5 are all low in nutritive value. They should not be used as a major feed source for milking cows because high fibre levels limit feed intakes. Milk responses to these feeds would be very poor and in most cases, uneconomical.

The term 'rice straw' covers an enormous range of types of straw. Modern breeding programs for rice have generally produced 'dwarf' varieties with short stems, to maximise the plant nutrients deposited in the seed head as rice grain. Consequently rice straws can vary from more than 50 cm in length down to 20 cm or less. With different stages of maturity at harvest, they can also vary widely in energy, protein and fibre contents. In reporting the feeds offered to livestock, many researchers fail to report the variety of rice straw, or even its physical characteristics, such as straw length or stage of maturity of the crop at harvest. This makes it very difficult for readers to fully comprehend their data on nutritive value, hence usefulness in dairy feeding systems.

Table 10.4 Nutritive value of some common South-East Asian forages

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). See Table 10.1 for details of UDP supply: high (H); good (G); moderate (M); poor (P). (Sources: Wanapat and Wachirapagoin 1990 and J Moran unpublished 2003)

Forage	DM (%)	CP (%)	CF (or NDF) (%)	ME (MJ/kg DM)	TDN (%)	UDP supply
Grasses						
Napier grass (immature)	13	11.3	(74.5)	7.6	51	P
Napier grass	22	9.5	30.8	8.3	55	P
Rhodes grass	29	7.9	36.8	8.8	58	P
Guinea gras	25	10.3	32.7	7.7	52	P
Para grass	26	11.8	31.6	8.5	56	P
Star grass	32	7.6	34.2	7.0	48	P
Pangola grass	21	10.6	28.0	8.3	55	P
Forage sorghum	16	16.3	(72.1)	7.7	52	P
Native pasture	31	7.6	(58.2)	7.9	52	P
Sudan grass	28	5.9	33.6	10.1	65	P
Maize silage	28	8.3	24.2	10.3	66	P
Legumes						
Centro	19	23.5	31.7	7.4	50	P
Peuro	31	17.9	27.1	10.1	65	P
Leucaena	32	18.7	37.8	7.9	53	P
Leucaena leaf hay	91	26.7	16.3	11.6	73	M
Stylo	25	17.3	24.5	-	-	P
By-products						
Maize stover hay	91	6.5	34.0	8.7	57	M
Maize stover 1	23	5.7	26.4	8.7	57	P
Maize stover 2	18	7.3	(69.3)	7.2	49	P
Sorghum stover	25	6.0	28.1	10.9	69	P
Sweet corn cobs	23	9.1	30.0	9.2	60	P
Cassava hay	90	24.7	17.3	8.5	56	M
Soybean	26	15.0	26.3	9.9	64	P
Field bean leaf and stem	11	17.1	23.2	9.8	63	P
Peanut leaf and stem	26	18.5	26.3	9.6	62	P
Soybean leaf	28	23.0	20.8	11.1	70	P

Table 10.5 Nutritive value of some common South-East Asian forage supplements.

Crude Fibre (CF); Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME); Neutral Detergent Fibre (NDF); Total Digestible Nitrogen (TDN). See Table 10.1 for details of UDP supply: high (H); good (G); moderate (M); poor (P). (Source: Wanapat and Wachirapagoin 1990)

Feed	DM (%)	CP (%)	CF (%)	ME (MJ/kg DM)	TDN (%)	UDP supply
Rice straw	92	4.2	42.3	6.4	45	P
Urea-treated rice straw	93	7.4	-	8.1	54	P
Banana stem	5	3.2	19.1	9.6	62	P
Sugar cane tops	26	5.0	32.6	7.2	49	P
Bagasse	95	3.0	43.1	7.4	50	M

10.5 Categorising supplements on energy and protein contents

To simplify the selection of forages and supplements for milking cow diets, those in the above four tables have been categorised into poor, moderate and good suppliers of dietary energy and protein in Table 10.6. Energy levels have been categorised as poor (<8 MJ/kg DM of ME), moderate (8–10 MJ/kg DM of ME) or good (>10 MJ/kg DM of ME) while protein levels have been categorised as poor (<10% CP), moderate (10–16% CP) or good (>16% CP).

Table 10.6 Classification of supplements and basal forages in Tables 10.2, 10.3, 10.4 and 10.5 according to their energy and protein contents

Crude Protein (CP); dry matter (DM); Metabolisable Energy (ME).

Energy/protein classification	Poor energy (<8 MJ/kg DM of ME)	Moderate energy (8-10 MJ/kg DM of ME)	Good energy (>10 MJ/kg DM of ME)
Poor protein (<10% CP)	Rice straw Urea rice straw Maize stover 2 Sugar cane tops Cassava waste 1 Bagasse	Rice bran 2 Most grasses Maize stover 2 Sweet corn cobs Banana stem	Cassava chips Dried cassava waste 2 Paddy rice Molasses Sweet potatoes Pineapple waste Corn silage
Moderate protein (10–16% CP)	–	Brown rice Well-managed grasses Soybean	Maize Sorghum Rice bran 1 Wheat pollard Palm kernel cake Sweet corn waste
Good protein (<16% CP)	Urea	Whole cottonseed Shrimp waste Cassava hay Most legumes Legume hays	Brewers grain Coconut meal Soybean curd Kapok seed Commercial concentrate Protein meals Legume leaves

10.6 Agro-industrial by-products

Many of the supplements included in the above tables are agro-industrial by-products. The storage of wet by-products has been discussed in Chapter 9. Some of the important dry by-products are described below.

Paddy rice: There are many forms of rice by-product concentrates resulting from processing paddy rice for human consumption, with nutritive value varying with the degree of contamination by rice hulls. Rice pollard contains minimal hulls but is generally used by pig and poultry farmers. Table 10.1 presents data for two grades of rice bran (1 and 2), varying in rice hull contamination. Rice bran quality can be subjectively assessed by gently blowing the bran as it drops from one hand to another. The more hulls that can be blown away, the lower the nutritive value. Chemical treatment of rice straw is discussed below.

Maize: There are many by-products from processing maize grain in western countries, some of which may be available to small holder dairy farmers in the humid tropics. The most important is maize gluten, the residue after extraction of maize starch and maize syrup. It is sold either as maize gluten meal or maize gluten fed, the latter including the bran. Wet maize gluten meal is produced as a by-product of the wet milling of maize grain. Other by-products, often used as feeds for pig and poultry, are first, maize steep liquor or distilled solubles, a condensed fermented maize soluble with maize meal and bran, and second, maize distillers grains. These by-product all have ME levels of 13 to 14 MJ/kg DM and CP levels of 11% to 30%, with gluten meal having 47% CP. Other by-products include mill mix (mixture of bran and pollard), hominy (or grits) and maize cobs.

Wheat pollard: arises from milling wheat into flour. It is a major component of formulated dairy concentrates in countries such as Indonesia.

Hulls: from cottonseed, peanuts and soybeans are low in energy and protein and high in fibre. They are quite palatable.

Palm kernel cake: is the by-product residue following extraction of oil from oil palm fruit. The oil content can vary from 2% to 10% depending on the method of extraction (solvent or pressure). Other by-products from oil palm processing are palm oil sludge and palm pressed fibre.

Oilseed meals: such as cottonseed, sunflower and soybean meals, and palm kernel cake, are residues from oil extraction, and vary in oil (hence energy content) depending on the extraction method.

Whole cottonseed is the residue of ginning cotton. It is either white (containing some cotton lint) or black in colour (with all lint removed). The white cottonseed is high in digestible fibre while both types have high oil contents. Whole cottonseed contains gossypol, which can be toxic, particularly to young stock.

10.7 Chemical treatment of low quality roughages

With the abundant supply of rice straw throughout South-East Asia, considerable effort has been directed towards improving its nutritive value. This had led to a plethora of feeding systems utilising chemically treated rice straw developed for the wide variety of ruminants, ranging from breeding stock to growing stock to milking cows (Doyle *et al.* 1986). The high nutrient demands of lactating cows limits the proportion of their diet based on modified rice straw, particularly when fed to produce high milk yields.

Table 10.7 presents data from a metabolism study conducted with Zebu bulls in Indonesia (Moran *et al.* 1983) where rice straw was treated with alkali and supplemented with Leucaena and compared to freshly harvested Napier grass.

Table 10.7 Nutritive value of rice straw-based diets in Zebu beef bulls fed to appetite

Diets are 100% rice straw (RS), alkali-treated rice straw (ARS), 70% RS plus 30% Leucaena (RS-L), 70% ARS plus 30% Leucaena (ARS-L) and 100% Napier grass (NG). (Source: Moran et al. 1983)

	RS	ARS	RS-L	ARS-L	NG
DM intake (kg/d)	5.1	3.6	6.6	5.9	5.4
DM digestibility (%)	37.6	46.9	42.1	47.8	52.7
Energy digestibility (%)	41.6	54.7	47.7	50.6	55.3
ME content (MJ/kg DM)	5.4	6.9	7.0	7.2	8.9
Nitrogen balance (g/d)	–3.1	–10.0	20.5	20.3	14.1

Many dairy farmers in South-East Asia have constructed cement boxes to make urea-treated rice straw, which is supposedly a good forage source for milking cows.

Alkali treatment improved digestibility of the dry matter and of energy and Metabolisable Energy content, but reduced dry matter intake. Even when alkali treated and supplemented with 30% Leucaena, the Metabolisable Energy content only improved from 5.4 (untreated rice straw) to 7.2 MJ/kg DM (treated rice straw plus Leucaena), still lower than that of Napier grass (8.9 MJ/kg DM). The Leucaena supplement improved the nitrogen balance in the cattle above that of Napier grass (20 v 14 g/d).

The Metabolisable Energy content of rice straw, both untreated and alkali treated, are lower than those reported in Table 10.5, indicative of the large variability in nutritive value of forage by-products. The poorer Metabolisable Energy content of the best diet based on alkali-treated rice straw, compared to the Napier grass, which is only a moderate quality roughage, indicates its limited potential role as a basal ration for milking cows fed to produce 15 to 20 L/d of milk.

Urea treatment of rice straw provides additional nitrogen, some of which will be converted to microbial protein if sufficient dietary energy is provided, although improvements in Metabolisable Energy content are likely to be less than those in Table 10.6. However, if fed *ad libitum*, intakes of urea treated rice straw would be greater than the untreated straw.

Table 10.8 presents the results from a study conducted in South Vietnam, in which crossbred Friesian cows were fed *ad libitum* diets based on Napier grass and rice straw ensiled with 5% urea (Mann and Wiktorssan 2001). The diets consisted of varying proportions of Napier grass and urea-treated rice straw plus a fixed amount of concentrate (0.4 kg per L milk produced). The Napier grass contained 11.5% DM, 12.7% CP, 9.2 MJ/kg DM of ME, the urea treated rice straw had 37.8% DM, 14.6% CP and 8.7

Such cement boxes should be used to make silage, generally a better quality forage than urea-treated rice straw.

MJ/kg DM of ME, while the untreated rice straw contained 6.9% CP and 7.0 MJ/kg DM of ME.

When fed the 100% Napier grass diet, cows had significantly lower dry matter intakes than when fed the 75% Napier grass diet. This could be due to the lower dry matter percentage of the very succulent Napier grass. Dietary crude protein levels decreased with rice straw feeding but there was little difference in dietary Metabolisable Energy contents. Milk yields were similar on all four diets, although milk fat contents increased with feeding urea-treated rice straw.

Table 10.8 Feed intake and milk production in Friesian crossbred cows fed various proportions of Napier grass (*Pennisetum purpureum*) and urea-treated rice straw

Crude Protein (CP); dry matter (DM); dry matter intake (DMI); Metabolisable Energy (ME). (Source: Mann and Wiktorssan 2001)

Napier grass:urea rice straw ratio	100:0	75:25	50:50	25:75
Roughage DM intake (kg/cow per day)	7.3	8.6	8.0	8.0
Total DMI (kg/cow per day)	11.0	12.3	11.9	11.6
Total DMI (kg/100 kg LWT)	2.59	2.94	2.83	2.78
Diet ME content (MJ/kg DM)	9.6	9.5	9.4	9.4
Diet CP (%)	13.8	12.6	12.1	11.4
Diet DM (%)	16.2	20.4	24.4	31.6
Milk yield (L/cow perday)	10.2	10.0	10.1	9.8
Milk fat (%)	3.7	3.9	4.0	4.3
Milk protein (%)	3.1	3.1	3.1	3.2

An economic evaluation of the above study costed rice straw at 70 (Vietnam dong) VND/kg to purchase, its urea treatment at 182 VND/kg and purchased Napier grass at 196 VND/kg. Feed costs were then 670 VND/kg DM for urea-treated rice straw compared to 1700 VND/kg DM for Napier grass or 2.5 times less expensive.

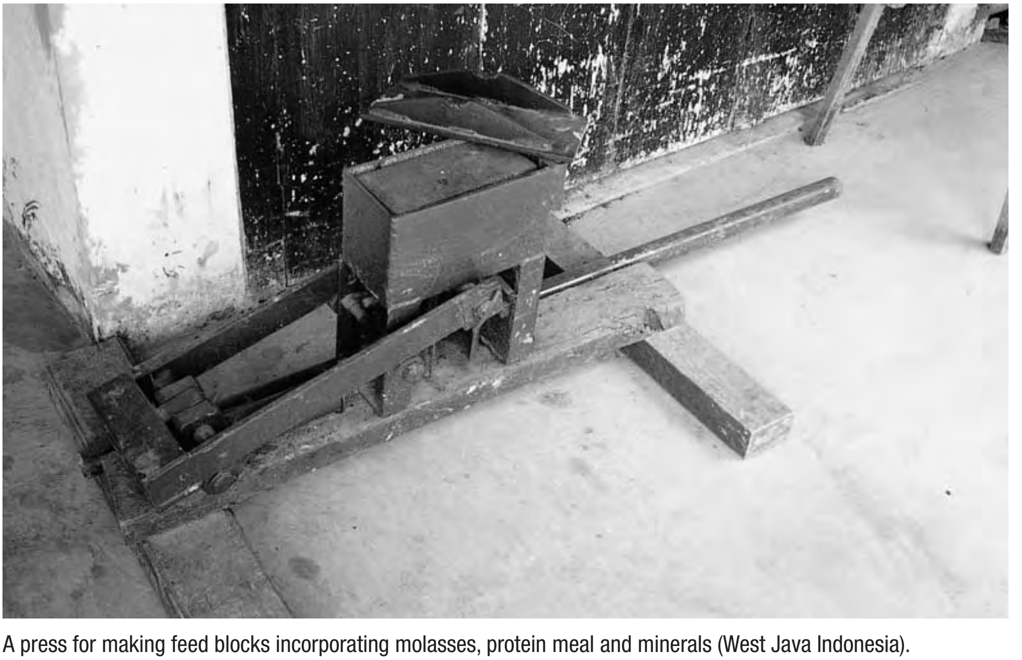
Milk responses to chemical treatment of rice straw may vary with the type of rice straw. The rice straw used in Table 10.7 originated from an early maturing variety (7.0 MJ of ME/kg DM) whereas that used in Table 10.6 was a later maturing variety (5.4 MJ of ME/kg DM).

The fact that only a few farmers in Asia have adopted chemical treatment of rice straw raises many questions. In the first instance, has the technology been extended to farmers correctly and if so, why then has it not been more widely adopted? Is this due to conditions of pretreatment which may not lead to significant improvements in nutritive value when the process is carried out on farm, or is it, because the process is not economical?

10.8 Molasses urea blocks

With urea being considerably cheaper than most protein supplements, it can form a cost-effective supplement, provided there is a readily available carbohydrate source to allow the rumen bacteria to convert the urea into microbial protein. When urea and molasses were made into lick blocks and offered to milking cows together with formulated concentrates and rice straw, Preston and Leng (1987) observed reduced intakes of the formulated concentrates and/or increased rice straw intake. This led to small milk responses in low yielding cattle and buffaloes, producing only 4 to 6 L milk/d.

By incorporating molasses and urea into a solid block, additional nutrients such as specific minerals or veterinary drugs such as anthelmintics can be easily included in the blend. There is considerable interest in developing high quality feed blocks incorporating mixtures of protein sources, such as rice bran, cottonseed meal and fish meal, which may be useful in higher yielding stock.



A press for making feed blocks incorporating molasses, protein meal and minerals (West Java Indonesia).

Once adequate quality forage is available to provide the energy required, milk responses to manipulating the proportion of protein as undegradable dietary protein or even providing additional nitrogen in the form of urea, are more likely to be economical and sustainable. As with chemical treatment of rice straw, adoption of nutrient feed blocks by small holder farmers has been slow, presumably because of the extra effort required to present the feed to the cows. Farmers are driven by profit margins, and even though labour costs are often not included in any profit calculations, extra effort must lead to considerably higher milk sales or lower feed costs or else it is 'not worth it'.

The proud Indonesian dairy farmer who designed the press (shown in the photo on p. 111) with some of his feed blocks

11

Milk responses to supplements

This chapter:

Explains why milk responses to supplements are not consistent and when a supplement becomes profitable to feed.

The main points in this chapter:

- milk responses depend on the substitution of basal forage for supplement
- supplements can affect milk production or cow condition. The total effect on milk production may not be immediate, but during the following lactation
- milk responses to supplementary feeding depend on stage of lactation, the amount, quality and presentation of both the basal forage and the supplement, cow condition, and level of production
- the profitability of supplementary feeding depends on the cost of supplements and the response in milk production, body condition or reproductive performance.

Supplements are fed to improve or maintain milk production, cow condition or reduce intakes of basal forages, when in short supply. Basal forages are the major forages fed by small holder dairy farmers, while supplements include all the additional feeds offered to improve cow performance. Where milking cows can graze for much of the day, the basal forage would be pasture.

The effect of supplementary feeding can be difficult to assess because the results may not appear immediately as milk. In the short term, the response to a particular supplement may be small. But if that supplement is used to 'save' on other feeds, for example, until the basal forages become more readily available or until a lower-priced supplement (eg crop residue) can be used, then it may be important and ultimately profitable.

The factors affecting responses to supplementary feeding are numerous (Figure 11.1) and their interactions are complex.

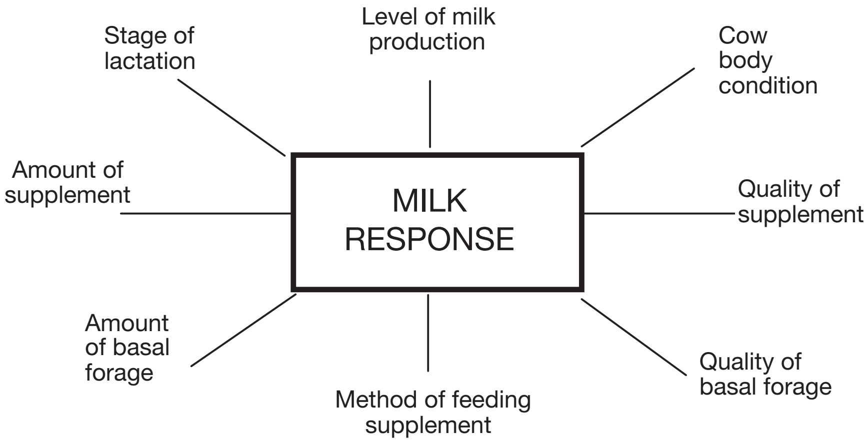


Figure 11.1 Some of the factors influencing milk responses to supplementary feeding.

11.1 Substitution for basal forage

Dairy cows may eat less basal forage when supplements are fed. The term 'substitution' describes the extent to which a supplement replaces the forage which would otherwise have been eaten had the supplement not been offered. The substitution rate is the reduction in forage dry matter intake (DMI) per kg dry matter of the supplement offered. A substitution rate of 0.25 then means that for every kilogram of dry matter of supplement eaten, forage intake will fall by 0.25 kg DM.

The major factor influencing substitution rate is the level of forage intake achieved with no supplements fed. If the supplements are fed when the forage has not been well utilised, it is likely that there will be little response in milk production and much of the forage will be wasted.

Substitution rates vary with:

- amount of forage offered each day – as more forage is offered, substitution is likely to increase
- intake limit of the cow – the closer the cow is to the limit of her feed intake when a supplement is offered, the greater the substitution
- quality of forage – if the forage is the same or poorer quality than the supplement, then the supplement may be eaten first
- type of supplement – substitution is generally greater with roughage (hay, silage) compared to concentrate supplements; this reflects the volume the supplements occupy in the rumen and how quickly they are digested to make room for more feed (ie roughages are bulky and are digested slowly)
- balance of the diet as a result of feeding the supplement – if the supplement corrects a dietary imbalance, less substitution occurs and intakes may increase; however, if an imbalance is made worse, total intake may be reduced.

11.2 How cows respond to supplements

11.2.1 Decreasing marginal responses

As the intake of energy increases, the amount of extra milk produced from each extra unit of energy decreases. In other words, the marginal, or additional, milk response decreases as the level of supplement intake increases.

The major reason for this decreasing marginal milk response is that, with successive increments of feed energy, the cow increasingly partitions nutrients from milk production towards body tissue deposition as milk production approaches the cow's genetic potential. In addition, the stage of lactation has an influence on how much of the supplement's nutrients 'go into the bucket' and how much 'go on the back'. Cows in early lactation tend to lose weight to divert additional nutrients towards milk while those in late lactation tend to repartition nutrients to replace previously lost body reserves (see also Chapter 7).

A second reason for declining marginal responses is that utilisation of one feed type can change with increasing intake of a second feed type, which is known as an 'associative effect'. Efficient digestion of forages, particularly low quality forages, requires an adequate population of fibre-digesting microbes in the rumen. By feeding increasing amounts of high starch concentrates, the proportion of these microbes will decrease as more starch digesting microbes propagate as a result of the higher starch intake. Consequently the digestion of the forage can decrease with increasing intakes of such concentrates. Additional starch excretion may also occur, further reducing feed utilisation. This can be particularly important when feeding high levels of supplements rich in fermentable carbohydrates, as rumen pH can decrease, dramatically reducing fibre digestion.

Supplementary feeding usually results in higher total feed intakes. Increasing intakes are the result of decreased times that consumed feed spends in the rumen where it is exposed to microbial breakdown. If less of that feed is digested and the nutrients are absorbed into the blood stream or pass down the digestive tract, less dietary energy becomes available for use by the animal. The cow partly compensates for this through decreased losses of energy via methane and urine with increasing feed intake. Although this may not be important unless total feed intakes dramatically increase through supplementation, it can contribute to declining marginal milk responses to supplements.

Another factor decreasing milk responses is the often incorrect assumption that all of the supplement is actually consumed. Rarely is there nil wastage, particularly if the supplement is a roughage. Fortunately, stall feeding minimises such wastage, compared to feeding cows while outdoors.

The major difficulty when predicting milk responses to supplementation, even if substitution rates are known, is the lack of information on the relative importance of the above factors. Without such knowledge, dairy advisers can only, probably incorrectly, assume additive effects when feeding a mixture of various feed types, which would tend to overestimate such milk responses particularly when:

- there are marked differences between basal roughages and supplement type
- large amounts (say 5 kg DM/cow per day or more) of supplement are fed.

11.2.2 Immediate and delayed milk responses

Responses to supplementary feeding have both immediate and delayed components. Some of the supplement goes immediately to milk production and some goes to body fat, which contributes to milk production at a later stage when this condition is mobilised.

To manage the feeding of supplements effectively, it is important to know how cows respond to them. The response is variable. It depends on the circumstances in which the supplement is fed.

The response in milk yield is generally due to the extra energy in the supplement. Unless the supplement improves the use of nutrients already in the diet or stimulates intake of the basal forage, farmers will not get any more milk than that produced from the energy the supplement contains.

In practice, forage substitution almost always occurs, resulting in the response being less than that predicted from the amount of energy in the supplement. The response will reduce at least by the equivalent of the energy in the forage no longer eaten. Also, some of the energy in the supplement goes to condition score rather than directly into milk. So the immediate milk response will be smaller again. Most experiments have only measured the immediate response to supplements. Because they are short term (usually only several weeks), they cannot measure the delayed milk response from body condition, hence the total milk response.

Most is known about the immediate response to supplements from studies in temperate countries. Whether these will be similar to responses in tropical countries requires further research. The major differences between temperate and tropical climate zones is the poorer quality of tropical forages and that many supplements are based on by-products, which vary greatly in nutritive value in tropical countries. Another difference may be the poorer quality control in feed mills, hence the greater variation in energy and protein contents of formulated concentrates in tropical countries. Therefore, it is highly likely that milk responses in South-East (SE) Asia will be lower than those in temperate countries.

Guidelines for temperate grazing dairy systems

In early lactation, the average immediate response to feeding concentrates containing 12 MJ/kg DM of metabolisable energy (ME) is 0.6 L of milk per kilogram of supplement dry matter, ranging from 0.2 to more than 1.0 L.

In mid-lactation to late lactation, the average immediate response is 0.5 L of milk per kilogram of supplement dry matter, ranging from 0.3 to more than 0.8 L.

One generalisation sometimes made is that 'you get half the response now and the other half later, when the condition score energy is converted back to milk'.

11.3 Factors affecting milk responses

When trying to quantify the response to a supplement, the main consideration should be whether the supplement meets the cow's need. The major needs are for quantity and quality of feed, both basal forage and supplement.

11.3.1 Quantity of basal forage

Roughages are generally the cheapest feeds available (see Chapter 8) and if sufficient are fed, these can meet the energy requirements for maintenance plus 8 to 10 L/d of milk, depending on forage quality. In peri-urban areas, where by-product supplements may be cheap and purchased roughage expensive, it might be more economical to reduce roughage to a minimum and increase supplements to a maximum. Fluctuations in roughage supplies could then be balanced by increasing supplements, depending on their relative prices.

If cows already have enough to eat, feeding more is unlikely to result in a big increase in milk production. However, hungry cows should give a good response.

There seems to be a good relationship between the amount of basal forage offered and the size of the milk response to supplement. When the quantity of basal forage offered is low, the response to feeding supplement is relatively large. High forage allowances result in little or no response to supplement feeding.

11.3.2 Quality of basal forage

Because of lack of land, most small holders in South-East Asia cannot allow their cows to graze freely as they do in temperate dairy industries. They then 'cut and carry' or 'zero graze' their cows that are tethered in sheds for up to 24 hours each day. The relatively low cost of labour means that the forage is harvested by hand and carried to the cow shed. Harvest intervals are based on compromises between maximising forage yield but also optimising forage quality (see Chapter 8). Unlike temperate grazing systems, small holder dairy farmers do not have to understand the principles of rotational grazing, optimum intervals between grazings and the selection differentials for different nutrients to calculate the nutritive value of forage selected in relation to that on offer.

If the forage quality is as good as the quality of the supplement it replaces, and provided the amount of forage does not limit intake, responses will be small or nil.

If the forage quality is low compared with the supplement quality, responses will be better. This is due to the supplement containing more nutrients than the forage it replaces and because feed of higher quality has a positive effect on total energy intake.

These observations can be expressed simply:

- the more suitable a forage is for milk production, the lower will be the response to a concentrate, whereas
- when forage quality is low and concentrates are able to provide limiting nutrients to the diet, the response will be better.

In a review of published cow performance data on Napier grass-based diets, Muia *et al.* (2000) classified grass quality according to the crude protein requirements for various categories of milking cows based on milk yields. These were for cows at maintenance (5–7% Crude Protein, CP), or producing low (8–10% CP), medium (11–13% CP) and high (14–16% CP) yields of milk. They then predicted feed intakes and cow performance in cows fed various diets differing in Napier grass quality and level of supplements, which were either concentrates or *Leucaena*. These data are presented in Table 11.1, while other relevant data of forage quality and yields of Napier grass have been presented in Table 8.12.

Increasing forage protein content (and other quality measures as shown in Table 8.12) generally led to increasing dry matter intakes per unit live weight. At low levels of supplementation, intakes were stimulated, presumably through higher total dietary protein contents. However, above 30% supplementation, the supplement substituted for forage, up to 50% substitution rate with 60% concentrate in the total diet. *Leucaena* supplementation had little effect on milk yield, presumably because energy was still the limiting factor not supplied by the supplement.

Table 11.1 The effect of forage protein content of Napier grass (*Pennisetum purpureum*) on intake of forage and total dry matter intake (DMI) and on cow performance when supplemented with either concentrates or Leucaena

*Substitution rate is the reduction in Napier grass DM intake per kg supplement DM intake (kg/kg) (Source: Muia et al. 2000)

Forage protein content	5–7%	8–10%	11–13%	14–16%
Concentrate supplemention				
Forage intake (kg DM/d)	10.2	8.2	7.2	4.7
Total DMI (kg/d)	10.2	9.3	10.7	12.3
Total DMI (g/kg$^{0.75}$ per day)	115	113	121	130
Concentrate %	0	12	33	62
Substitution rate*	0	-0.12	0.27	0.54
Milk yield (L/d)	7.6	8.6	9.2	12.4
Live weight change (kg/d)	-0.5	0.0	-0.1	0.1
Leucaena supplemention				
Forage intake (kg DM per day)	6.8	7.1	7.0	-
Total DMI (kg/day)	6.8	8.2	9.3	-
Total DMI (g/kg$^{0.75}$ per day)	83	99	106	-
Leucaena %	0	13	25	-
Substitution rate*	0	-0.22	-0.02	-
Milk yield (L/d)	6.0	6.5	7.1	-
Live weight change (kg/d)	-0.4	0.0	0.1	-

Feeding Napier grass alone supported milk yields of 6.8 L/cow per day, but this was accompanied by live weight losses of 0.4 kg/d. The maximum predicted yield (12.4 kg/cow per day) in Table 11.1 was below expectation (15 L/cow per day), possibly due to shortages of readily fermentable nitrogen for optimum rumen microbial activity (Muia *et al*. 2000).

11.3.3 Quality of supplement

Milk responses vary greatly with supplement quality. In temperate grazing systems, cows generally produce less milk per kilogram of hay Dry Matter than per kilogram concentrate Dry Matter, because of the lower energy and higher fibre content in the hay. This would also be the case in South-East Asia. Therefore, it could be argued that milk responses to feeding very low quality forages, such as rice straw or sugar cane tops, would be even lower than those from formulated concentrates or other energy supplements, such as those described in Chapter 10. However, such feeding decisions are usually made as a result of large shortages in basal forages.

Tree legumes can replace some of the concentrates in supplement feeding strategies. In their review on forage production for small holder farmers in Thailand, Nakamanee *et al*. (1999) reported on African studies in which 3 kg fresh *Calliandra* forage had the same effect on milk production as 1 kg formulated concentrate. Another study recorded a 1 L/d milk response in cows fed 8 kg *Leucaena* to supplement a Napier grass-basal forage.

11.3.4 Allocation of supplement

The overall response in milk yield to concentrate feeding during early lactation depends on the extent to which residual effects on milk yield persist later in lactation. These residual reponses can be expressed later in the same lactation or in the following lactation. Unless the high nutrient demands during early lactation (as discussed in Chapter 7) are met, this can affect cow performance later in lactation.

Using Friesians and Ayrshire milking cows in Kenya, Kaitho *et al*. (2001) demonstrated the production benefits of good feeding management in early lactation. All 18 cows in this trial were fed the same total quantity of concentrates for 300 days (600 kg/cow) but using three different allocations: A, 2 kg/d over 300 days; B, 4 kg/d over the first 150 days; C, 8 kg/d over the first 75 days of lactation. The basal diet was *ad libitum* Rhodes grass (*Chloris gayana*) hay (containing 8% protein and 65% Neutral Detergent Fibre, NDF) while the concentrate was a commercial dairy meal (with 15% protein) fed twice daily. Cows weighed 400 kg at calving and their performance is presented in Table 11.2.

Table 11.2 Measures of cow performance in Friesians and Ayrshires in response to three different allocations of concentrates while fed Rhodes grass hay (*Chloris gayana*) *ad libitum*

Allocation: A, 2 kg/d for 300d; B, 4 kg/d for first 150 d; C, 8 kg/d for first 75 d; *, statistical significance; C is significantly different to A and B. (Source: Kaitho *et al*. 2001)

	A	B	C
Milk yield			
Days 1–75 (kg/d)	12.1	13.2	17.5*
Days 75–150 (kg/d)	8.1	8.4	10.2*
Days 150–300 (kg/d)	6.8	6.3	7.2
Entire lactation (kg)	2544	2562	3155*
Live weight change			
Days 1–75 (kg/d)	–0.38	–0.16	0.17*
Days 75–300 (kg/d)	0.13	0.24	0.21
Reproductive performance			
Calving to conception (days)	106	99	80*
Services per conception	2.2	2.0	1.5

Cows allocated their entire concentrates during their first 75 days of lactation produced more milk in early and mid-lactation and for their entire lactation. They gained weight prior to mating (in contrast to the other two groups that lost weight), hence conceived earlier with fewer services per conception (although this was not statistically significant). Body condition scores, not presented in Table 11.2, improved over the lactation and were always higher in group C than in groups A and B. Milk fat contents did not differ between groups, averaging 3.2%.

Cows have limited gut capacity following calving hence must be fed higher quality diets. The lag of maximum intake behind peak milk yield leads to negative energy balance with cows having to utilise body reserves, to the detriment of their reproductive performance if this energy deficit is too severe. Furthermore, such losses in milk production caused by under feeding cannot be overcome even if the ration is balanced later in lactation. Group C cows, even when fed no concentrates between days 75 and 150 still produced more milk during these 75 days than the concentrate-fed groups A and B.

Therefore, a simple management decision, such as reallocating the same amount of concentrate supplements, can improve milk production and reduce calving intervals. In this study, these benefits were 611 kg milk/cow plus a 26-day shorter calving interval.

11.4 Presentation of the forage and supplements

Milking cows can be offered their diet in many ways:

- grazing the forage and hand fed the concentrates at milking
- grazing the forage, supplemented with additional forages at pasture or on a feedpad and hand fed the concentrates at milking
- zero grazed hence hand fed the entire diet in the shed
- lot fed on total mixed rations, in which forages and concentrates are presented as a blended ration.

The presentation of the diet can influence milk responses in various ways.

11.4.1 Presentation of the forage

Wilting the forage

The optimum total diet dry matter for maximal dry matter intake is 50% to 75%, which can limit the quantity of freshly harvested forage that should be fed, particularly in early lactation.

Large-scale wilting of freshly harvested forages improve feed intakes and milk yields.

With regard to forages, levels of water that exceed 22% (or feeds <78% DM) can restrict forage intake. For example, Minson (1990) reported that for every 1% increase above 82% water content, or for every decrease of 1% unit below 18% DM, forage intake decreased by 0.34 kg DM/d in lactating dairy cows.

Wilting fresh Napier grass for 24 hr increased

Small holder farmers can easily wilt the day's allocation of forage for their stock, prior to feeding.

forage intake and nutritive value in beef cattle and buffaloes (Table 11.3). The Napier grass was harvested every 45 days during the wet season and contained 12% DM, 7.5% CP and 62.2% NDF. The climatic conditions were such that dry matter percentage only increased by 2.6% units following a 24 h wilt. Grant *et al.* (1974) concluded that the loss of moisture was not a factor in increasing digestibility, but it was the result of some chemical or enzymatic changes taking place during the wilting period.

Table 11.3 Effect of wilting fresh Napier grass (*Pennisetum purpureum*) on intake and digestibility by cattle and buffaloes
(Source: Grant *et al.* 1974)

	Fresh	Wilted
Forage DM content (%)	12.0	14.6
DM intake (% LWT)	2.0	2.3
DM digestibility (%)	58.2	64.2
CP digestibility (%)	64.0	70.6
NDF digestibility (%)	54.3	60.8
ME content (MJ/kg DM)	7.9	8.9

McDowell (1994) suggests that wilting forages stimulate appetite through smaller rumen volumes of intracell water and improved rumination of the chewed forage. Furthermore, higher forage dry matter contents will produce a denser mat of predigested forage in the upper rumen, making it easier for this material to be regurgitated during rumination. A faster rate of forage breakdown in the rumen will increase the rate of passage of feed through the cow's digestive tract, hence a greater appetite for more.

Wilting racks can easily be constructed from bamboo and built off the ground to encourage air movement under the freshly harvested forage and so aid water removal from the leaves. Conditioning the thicker parts of the forage, to fracture the epidermal layers, will result in a faster rate of water removal from the plant. Forage can then remain on the wilting racks for up to 24 hr.

It is essential to stack the forage loosely on wilting racks in thin layers, no thicker than 10 cm. If the forage heats up during wilting, its nutritive value will decrease, due to plant sugars being used by bacteria and fungi during heating. In the case of heavy rain, a roof made of tarpaulin or thick plastic should be positioned above the wilting racks, allowing easy removal during sunshine. Rewetting of partially wilted forage requires longer wilting times, which will almost certainly reduce its nutritive value.

To quantify the benefits of wilting, cows in mid lactation were fed chopped Napier grass plus concentrate (6 kg/cow per day) in Indonesia (Moran and Mickan 2004). Wilting the grass for 8 hr increased daily intakes of fresh grass from 40 to 50 kg/cow and increased daily milk yields from 14.2 to 15.7 L/cow. Assuming the concentrate contained 90% DM, the fresh grass 17% DM and the wilted grass 20% DM, the wilting then increased total daily dry matter intakes from 12.2 to 15.4 kg/cow, a daily increase of 3.2 kg/cow. Clearly, wilting is a simple and practical method to improve intakes of freshly harvested forages, leading to increases in feed intakes and hence cow performance.

Chopping the forage

Prior to feeding, all forages should be chopped, either by hand or mechanically. This reduces the opportunity for cows to select from the forage, where they choose the more palatable leaves and reject the coarse stems. Even though the cows will select a diet with higher nutritive value from unchopped material, the wastage from rejected feed can be very high. Farmers may offer less forage, when hand chopping it, to encourage the cows to eat a greater proportion of it. However, in so doing, total forage intakes will be reduced and milk yields will suffer. It is preferable to remove the refusals and offer freshly chopped forage as often as practically possible, certainly two or three times per day.

Table 11.4 Effect of chopping fresh Napier grass (*Pennisetum purpureum*) harvested during the wet or dry season on intake and digestibility by cattle and buffaloes

NS, not significant; *, significant; **, highly significant. (Source: Grant *et al.* 1974)

	Whole	Chopped	Statistical significance
Wet season			
DM intake (% LWT)	1.9	2.0	NS
DM digestibility (%)	54.3	56.0	*
ME content (MJ/kg DM)	7.2	7.5	*
Consumed CP content (%)	7.8	7.6	NS
Consumed NDF content (%)	63.1	63.5	*
Dry season			
DM intake (%)	2.2	2.5	*
DM digestibility (%)	58.5	56.0	*
ME content (MJ/kg DM)	7.9	7.5	*
Consumed CP content (%)	6.6	6.2	**
Consumed NDF content (%)	64.3	65.2	**

Grant *et al.* (1974) compared the intake and utilisation of Napier grass harvested in different seasons and fed whole or chopped. They found that chopping it into 2 to 5 cm pieces increased intake, but only significantly during the dry season (Table 11.4). The Dry Matter digestibility (and hence calculated Metabolisable Energy content) of the grass improved through chopping in the wet season, whereas it was reduced in the dry season. Animals selected grass with higher protein and lower fibre contents when it was offered whole, compared to chopped.

Feeding conserved forages

Cows may consume less of the forage once it is conserved and it will invariably be of poorer nutritive value than when freshly harvested. If cows have never been fed silage, it may take several days before they fully adapt to its taste. Spoiled silage, due to its exposure to air during the ensiling process, is less palatable, and in certain situations, the toxic bacteria can make cows sick or even kill them. Mould in hay and silage will reduce its palatability. As with any forage, fresh or conserved, if it heats up, it will also have reduced palatability.

When designing silage stacks, consideration should be given to reducing the length of the feeding face, when opened, to reduce aerobic deterioration. Similarly, once removed from the silage stack, the longer the delay in feeding out, the more heated it will become. Hot silage has poorer nutritive value that does cool silage (see Chapter 9 for further details about silage feed out management).

11.4.2 Presentation of the concentrates

The 'cut and carry' system provides the opportunity of farmers to reduce grain poisoning or lactic acidosis (see Chapter 13). When cows graze and are only offered concentrates at milking, they may have to consume 50% or more of their total diet within two 10 to 20 min periods. This is called 'slug feeding' because the bacteria in the rumen are suddenly exposed to large amounts of starch in two slugs each day. Rumen pH will invariably fall and fibre digestion may be reduced. At least with zero grazed cows, it is easier to offer smaller amounts of concentrates more frequently.

Preparing concentrate mixtures

It is rare for milking cows to be offered one type of concentrate only, because of their high nutritive demands and the poor nutritive value of tropical forages. Concentrate mixtures usually contain a variety of energy and protein supplements together with minerals, usually macrominerals, and for high yielding cows, maybe even microminerals.

One very simple method of preparing a complex concentrate mix for storage or immediate feeding is to spread each ingredient on top of each other in layers (even the mineral premixes) then collect the mixture into bags or buckets by shovelling it perpendicular to the floor. This method is ideally suited for dry concentrate ingredients, although it could be used each day for offering mixtures containing wet by-products such as cassava or soybean waste.

Molasses blocks are a good supplement, and can be used as carriers of non protein nitrogen or minerals. The blocks are solid, fairly easy to make, transport and store. Molasses intakes should not exceed 20% of the total intake, because at higher levels it will depress digestibility.

Many farmers in South-East Asia mix dry concentrates with water to make a slurry, prior to feeding. There is little benefit in this practice in terms of encouraging stock to consume more or improve its utilisation.

Formulation of concentrate mixture

Many dairy cooperatives throughout South-East Asia have feed mills producing formulated concentrate mixtures. The formulations are usually just for protein and are generally based on typical or 'book' values of nutritive values for the raw ingredients. However, when tested in feed analytical laboratories, such formulations are all too frequently incorrect because of the wide variations in the nutritive value of the raw ingredients.

Problems often exist in distribution to individual farmers, as quantities are small and transportation costs high. Distribution is often implemented by farmer cooperatives, which can also be combined with provision of credit, with deductions from milk payments. Cooperatives can also develop contracts with food processors, such as breweries or vegetable oil extractors, to maintain continuity of supply and control prices of such by-products.

The cost of the formulated concentrate can exceed that of the total of its raw ingredients, meaning that it may be more profitable for farmers to prepare their own mixtures. Ideally this requires frequent analyses of the raw ingredients, which is expensive and may not be accurate because poor resourcing of feed analytical laboratories is all too common. In this case, it would be better to base the formulation on undervalued estimates of energy and protein contents of both the concentrate ingredients and the forages. This can lead to incorporating more of the expensive ingredients in the mix, but such an approach is still likely to be profitable because very few cows are fed to their full potential in South-East Asia.

The profitability of feeding milking cows depends on the marginal cost of additional nutrients fed and the marginal return from extra milk produced, so any extra milk produced as a result of overfeeding some nutrients, above the base level, is often a profitable exercise.

Energy, rather than protein, is the most common limiting nutrient for the milking cow, so basing concentrate formulation on protein may still lead to underfeeding them below their potential. Furthermore, the incidence of induced protein deficiencies in milking cows (see Section 11.5.1) is evidence of inappropriate formulation for protein. Unfortunately it is difficult to obtain accurate estimates of energy from laboratory analysis whereas accurate protein analysis is relatively easy, hence the use of protein as the basis of concentrate formulation.

11.4.3 Total mixed rations

Total mixed rations for milking cows should be based on reliable supplies of high quality forages. One successful example of developing such a system for small holder dairy farmers is in Banueng province, southern Thailand. The local cooperative grows large areas of forage maize for silage, which it then mixes with several by-products such as pineapple pulp, cassava waste, palm kernel cake, white cottonseed and maize grain. These are blended in a stationary mixer wagon, placed in large wool sacks, each holding about 500 kg, then delivered each day to nearby farms for immediate feeding. Dry cows are fed a blended mixture of maize silage, rice straw and concentrates.

Feedlotting cows

Several large-scale dairy feedlots operate in Indonesia and Thailand. These operate with similar management systems to feedlots in developed countries, in that the cows are all owned by a single owner, usually a corporate organisation. A value adding operation, such as an Ultra-High Temperature (UHT) milk processing and packaging plant is often constructed near the feedlot, to maximise profits from the capital intensive enterprise.

The forage supply is often based on small holder cropping farmers in which case considerable negotiations are required to ensure continuous quality control, for example ensuring the forage maize supplied is whole crop (complete with the cob) and not maize stover. As the feedlot depends entirely dependent on small holders, goodwill is essential as contractual obligations may not always be honoured.

Cow colonies

Although these are rarely based on total mixed rations, they allow for more controlled management of small holder farming operations. Sheds of up to 200 cows house stock owned by many farmers (eg each with 5–10 cows) where forages are freshly harvested from near their farms. Frequently the local dairy cooperative owns all the facilities, which may include forage producing areas, silage pits and an effluent recycling system. Well-resourced cooperatives (or local government agencies in countries such as China) even construct a milking parlour for machine milking, rather than hand milking, in the farm complex. Unfortunately, in certain instances, the shed was built and filled with stock prior to the guaranteed regular supply of improved forages. In these cases, rice straw may be the only back up forage, with a consequent marked decline in cow performance.

Each farmer is responsible for the feeding and managing their own cows, but the high concentration of cows can allow for the development of machinery and specialist skills (eg forage choppers, milking machines). Cow colonies generally lead to large-scale calf and heifer rearing sheds, thus allowing for easier monitoring of improved small holder dairy management systems, such as milking hygiene. Furthermore, the shed is generally well constructed in contrast to those on most small holdings.

A cow colony in West Java, Indonesia, where many small holders house their stock in a large shed.

Inside a cow colony in West Java, Indonesia, where many small holders house their stock in a large shed.

Complete diets

There is increasing interest in producing complete diets that can be stored for lengthy periods then easily transported to small holders (eg as feed blocks) in times of forage shortages. Unlike beef cattle and small ruminants, milking cows require at least 40% of their diet as forage, and offered in large particle sizes (not finely ground as required to produce feed blocks), meaning that it is not easy to produce an easy-to-handle complete diet. It would be possible to produce a complete diet using alternative roughage sources, such as ground nut shells.

Furthermore, using fresh forages as the forage source (as against straw) requires a major cost in drying such material. Entrepreneurs in Australia have developed a forage-drying shed based on black roof and walls and pumped hot air into a grass drying chamber. Excess forages are usually available only during the wet season making them difficult to field dry to at least 85% DM as the lack of solar radiation would necessitate the use of auxiliary power based on fossil fuels. Such complete diets would be prohibitively expensive, particularly for cash-poor small holder dairy farmers.

11.5 Specific examples of incorrect supplementary feeding practices

11.5.1 Induced protein deficiencies

In many tropical countries, one often finds very fat cows only producing a little milk. This is a classic symptom of induced protein deficiency, brought about by feeding low protein supplements to cows already eating low protein basal forages. The easiest way to diagnose this problem is to monitor milk responses to the supplement, then increase the protein content of the supplement, and note any changes in milk response. If the second milk response is greater than the energy contained in the additional protein fed, the initial diet (of basal forage plus supplement) is likely to have induced a protein deficiency.

11.5.2 Feeding inappropriate supplements

In most tropical feeding systems, the major limiting factor is energy. Unfortunately, there is increasing publicity from commercial enterprises that milk responses can be improved by feeding 'Brand X' supplement containing additional vitamins and minerals or 'Brand Y' supplement containing probiotics or rumen modifiers (these can improve rumen digestion, hence feed utilisation). These particular supplements have been developed for intensive feeding systems, such as dairy feedlotting in temperate countries.

They are often called 'magic bullets' because their manufacturers claim excellent milk responses (and improved cow performance) in many different feeding systems. They may be appropriate for intensive dairy systems where cows can consume sufficient dietary energy and protein, such that other nutrients are limiting milk responses. Furthermore, in these feeding systems, cows may be producing 30 L/d or more, not the 10 to 15 L/d typical of small holder dairy systems.

When confronted with such publicity, farmers and advisers should query their relevance unless the information includes results from studies specific to the small holder dairy systems for which they are being promoted. Furthermore, the independence of the researchers undertaking any relevant studies needs to be assessed. In many cases the farmers' money would be better spent on increasing supplies of dietary energy (or protein if feed supplies are adequate) to the current system.

Unless sufficient dietary energy is offered, milk responses to other forms of nutrient supplements are not likely to be large, or profitable.

11.5.3 Feeding milking cow supplements to young stock

Throughout South-East Asia, most formulated supplements for milking cows are formulated to 16% CP, even though on closer investigation (J Moran unpublished 2003), they are frequently below this content. For convenience, many small holder dairy farmers also feed these concentrates to their young stock. Such formulations are far from ideal because, for optimal growth and health, milk-fed calves and weaned heifers require 18% CP in their total diet (basal forage plus supplements). Depending on the quality of the basal roughage fed post-weaning, 18% may be insufficient for the concentrates.

Very rarely can small holder farmers purchase higher protein formulated concentrates and all too often they are not even aware of the benefits for their young stock in supplementing available milking concentrates with additional protein supplements.

High protein concentrates may be available, but at great expense, as they have been formulated for pig and poultry and incorporate high-quality protein ingredients. It would be ideal if a few large-scale feed mills, either owned by dairy cooperatives or agribusiness, could formulate calf and heifer mixes with higher protein contents, utilising better quality energy sources and additional minerals and vitamins for optimal growth of young stock. Compared to the higher demand of concentrates specially formulated for milking cows, the formulation of smaller batches of calf and heifer mixes would not be cost effective for small dairy cooperatives.

11.5.4 Excessive use of supplements

Overuse of concentrate supplements can reduce forage utilisation through metabolic disorders, such as lactic acidosis (see Chapter 13). As already mentioned in this chapter, associative effects reduce forage utilisation at high concentrate feeding levels.

If the cows are already well fed, overuse of concentrates can reduce milk responses because cows may already be producing relatively well. For example, increasing milk yields by 2 L/d, from 20 to 22 L/d requires more additional nutrients per litre of extra milk than increasing milk yields by 2 L/d, from 10 to 12 L/d.

Farmers must be the ultimate judges of whether milk responses to a particular supplement are sufficiently large (and profitable), based on observations of their herds' performance when fed certain basal forages. Farmers can then make their own decisions as to the most economic level of feeding of that supplement in their own system. Most farmers have a good idea of how their cows are performing and, with a little guidance, can learn to monitor the most appropriate production indices.

A simple test to determine the size of the response is to put 1 or 2 kg of supplement into the diet, or take 1 or 2 kg out, then monitor its effect on cow performance, such milk yield and forage intake.

11.6 Milk yield and total diet quality

11.6.1 Energy content of the diet

In temperate dairy systems, cows can produce 20 to 25 L/d of milk on grazed pastures alone. However, with the lower quality of tropical forages, it is essential to feed supplements to produce more than 8 to 10 L milk/d. Muia *et al.* (2000) only recorded cows fed 100% Napier grass to produce 6.8 L/d of milk (Table 11.1). McDowell (1994) estimated the total diet quality for various levels of Friesian cow performance (Table 11.5). These values underestimate the required metabolisable energy contents by up to 0.5 MJ/kg DM (J Moran, pers. obs.).

Table 11.5 Estimated required diet quality for expectations in performance
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: McDowell, 1994)

Expected cow performance	Level of milk production (L/d)	Estimated ME content (MJ/kg DM)	Estimated TDN content (%)
Maximum genetic performance	>35	10.0	>70
Intermediate performance	20–24	8.2	60
Medium performance	12–16	7.3	55
Low performance	3–6	6.5	50
Maintenance	–	5.6	45
Live weight loss	–	<4.8	<40

The higher the quality of the forage, the less concentrates necessary to achieve the desired milk yield. Devendra (1975) estimated the amount of concentrates required for target milk yields in 400 kg milking cows (non-pregnant with zero weight change) when fed *ad libitum* forage of varying qualities (Table 11.6). He assumed the concentrate to be home mixed and to contain 12.2 MJ of ME kg DM and 24% protein.

Table 11.6 Required concentrate intakes (kg DM/day) for cows fed forages of varying quality to achieve target milk yields
(Source: Devendra 1975)

Milk yield(L/d)	Forage quality Digestibility (or ME in MJ/kg DM)			
	55% (7.3)	60% (8.2)	65% (9.0)	70% (9.9)
6	3.2	0.7	–	–
10	4.9	2.5	0.8	–
14	6.6	4.8	1.1	0.3
18	8.2	6.0	3.0	0.7
22	9.8	7.7	5.4	1.7

In Indonesia, Hendrawan (2003) estimated the intakes of both concentrate and fresh grass required for target milk yields in cows of varying live weight and assumed zero live weight change (Table 11.7). Details of the grass were not provided whereas the concentrate was assumed to contain 87% DM, 18.2% protein and 77% TDN (or 11.1 MJ of ME/kg DM).

Table 11.7 Required daily intakes of concentrate (C) and freshly harvested grass (G) (kg/d) for cows of varying live weight to achieve target milk yields
(Source: Hendrawan 2003)

Milk yield (L/d)		Live weight (kg)				
		300	**350**	**400**	**450**	**500**
8	C	5.3	5.9	6.4	6.5	6.8
	G	30.0	32.0	34.0	36.0	38.0
12	C	6.5	7.1	7.4	7.7	8.0
	G	36.0	39.0	41.0	43.0	45.0
16	C	7.7	8.3	8.7	8.3	8.7
	G	43.0	46.0	48.0	46.0	48.0
22	C	9.6	10.1	10.4	10.7	11.0
	G	53.0	56.0	58.0	59.0	62.0

One example of a practical feeding system developed in Indonesia by Alim *et al.* (2001), for well-managed small holder farmers is presented in Table 11.8. This is for 500 kg cows, each producing 5000 L in their 3rd lactation while fed a mixture of forages (maize stover, Napier grass, field grass) and various concentrates (formulated mix with additional coconut meal and maize grain during early lactation). The recommended formulated concentrate should have 16 to 18% CP and 70% TDN (or 9.9 MJ of ME/kg DM). The quantities of roughage fed in Table 11.6 are considerably lower than those required for similar milk yields in Table 11.5, but this might be partly because of expected live weight changes in the year round system.

Table 11.8 Recommended feeding system for Indonesian small holder farmer utilising roughages (R) and concentrates (C). Units are L/d for milk and kg fresh/d for feeds

Roughages (R) are maize stover (MS), Napier grass (NG) and field grass (FG). Concentrates (C) are formulated concentrate (FC), cottonseed meal (CM) and maize grain (MG). (Source: Alim *et al*, 2001)

Month of Lactation	Milk Yield (l/d)	MS	NG	FG	FC	CM	MG	R	C
Pre Calving	–	15	45	–	3	–	–	60	3
1	23	22	15	–	10	1	1	37	12
2	23	30	–	–	15	1	1	30	17
3	21	30	–	–	12	–	1	30	13
4	19	10	20	–	11	–	–	30	11
5	17	10	20	–	10	–	–	30	10
6	15	10	20	–	9	–	–	30	9
7	14	10	25	–	8	–	–	35	8
8	12	–	15	25	7	–	–	40	7
9	11	–	15	25	6	–	–	40	6
10	10	–	15	25	5	–	–	40	5
Total	5000	4020	6255	2250	2930	60	90	–	–

11.6.2 Excess dietary protein

Milking cows require diets containing 12 to 18% CP, depending on their stage of lactation and milk yield (Target 10 1999). Milk responses to supplements can be reduced if dietary protein contents are outside these optimum levels. Induced protein deficiencies have been briefly mentioned in Section 11.5.1 but in rare instances there can also be a problem with induced protein excesses. It would not be common for small holder farmers to offer diets containing 25% or more of crude protein, with much of this protein as rumen degradable. This could occur for example, when supplementing immature grasses or legumes with concentrates rich in rumen degradable protein.

High levels of Rumen Degradable Protein lead to excess rumen ammonia, which must be detoxified in the liver in order to be excreted as urea in the urine. The metabolic costs associated with this process require energy, which would otherwise be used to produce milk. This 'urea cost' may result in 1 to 2 L/d less milk (Cohen 2001). Feeding cereal grains or supplements high in readily fermentable carbohydrates will allow rumen microbes to capture this Rumen Degradable Protein and synthesise microbial protein, for ultimate use by the cow to produce milk.

Diagnostic tests are available in developed countries to measure the urea content of milk, as an indicator of the imbalance of rumen degradable protein in the diet.

11.7 When is supplementary feeding profitable?

The economic effect of supplements should be assessed in relation to the overall farm feeding system. Nevertheless, it is the short-term milk response that impacts on immediate cash flow. Chapter 17 discusses a simple measure of profit, 'milk income less feed costs'.

It is not easy to assess whether supplements are providing extra profit for small holder dairy farmers without accurate information on immediate and delayed milk responses from particular feeding scenarios. The following are examples of such calculations and assume that milk responses are only half of those derived from temperate grazing studies.

11.7.1 Survival feeding

The profitability of supplements is easiest to determine when feed intake is well below cow requirements. It will not only be a matter of profitability, but of survival. The animal needs to be fed to survive.

11.7.2 Moderately well-fed cows

The next level is when cows are moderately well fed. A typical total milk response for concentrate supplements in small holder dairy systems in Thailand may be about 0.25 L now and perhaps 0.25 L later for each kilogram dry matter of supplement. A simple assessment of feed costs and profit in Thai baht or Bt would suggest break-even is when the cost of the supplement is equal to the value of the total milk response.

12 Bt/L (milk price)	× 0.25 L/kg DM of supplements fed (immediate response)	= 3 Bt
	× 0.25 L/kg DM of supplements fed (delayed response)	= 3 Bt
	Total benefit	= 6 Bt

In this case, it is profitable to feed the concentrate supplement if it costs less than 6.0 Bt/kg DM.

11.7.3 Well-fed cows

A third situation is when cows are well fed with basal forages but concentrate supplements are fed to increase milk yield. The total response from each kilogram of dry matter of supplement fed will be closer to 0.12 L now and perhaps 0.12 L in the next lactation coming from improved condition. The break-even point to make a profit from this can be estimated as before.

12 Bt/L (milk price)	× 0.12 L/kg DM of supplements fed (immediate response)	= 1.4 Bt
	× 0.12 L/kg DM of supplements fed (delayed response)	= 1.4 Bt
	Total benefit	= 2.8 Bt

The supplement would need to cost less than 2.8 Bt/kg DM for supplementary feeding to be profitable.

11.7.4 Other reasons for feeding supplements

Supplements are fed for their beneficial effects on more than just milk production. For example:

- Without supplementary feeding, cows may lose too much body condition, which could affect their ability to get 'in calf'.

- Basal forages may be in short supply and the only other feedstuffs available are very low quality forage supplements such as rice straw or sugar cane tops. Even though milk responses are very low, cow survival and subsequent fertility may be endangered without including such low quality forages in the feeding system.
- Feeding concentrate supplements may enable farmers to increase their herd size. This may be justifiable so long as the extra milking cows can be relatively well fed (see Chapter 17).

12

Formulating a diet

This chapter

Explains how to formulate a balanced diet that takes account of the production goals.

The main points in this chapter:

- diet formulation involves matching the feed supplied with the specific requirements of the herd in the most cost-effective way
- to provide the nutrients calculated as being required, it is important to know how much feed a cow is capable of eating
- intake capacity depends primarily on size and weight of the cow, quality of the feed on offer and stage of lactation
- supplements should be compared on the cost of the nutrients they contain
- worksheets are provided to calculate cow requirements, nutrients supplied in the diet and their cost
- computer aids are available to assist in formulating diets as four software programs.

Formulating a diet is an important part of an everyday feeding strategy. It is a means of meeting production and financial goals by feeding to the specific requirements of the cow in the most economical way.

To formulate a diet, farmers and advisers need to know the quantity of nutrients the cow or herd needs to meet production and animal health goals, and the nutrient content of the feeds available.

A balanced diet is then one in which 'cow nutrient requirements = nutrients provided in the diet'.

Another consideration in balancing diets is whether the cow is physically capable of eating the amount of feed provided. The final consideration is the economics. The economic response from feeding specific nutrients must be more than their cost. This aspect is often forgotten.

Ration formulation is then:

1 setting the production targets for each cow or the entire herd
2 assessing what home-grown feeds are available
3 deciding what feeds should be purchased
4 ensuring that the ration can be consumed to achieve the production targets
5 ensuring that the ration is the most profitable, both at present and over the entire lactation.

Diet formulation is largely a set of mathematical procedures. However, close observation of cows is also important. Herd production, fertility, body condition and health are all good indicators of nutritional imbalances.

12.1 Information needed to formulate a diet

12.1.1 Cow requirements

Cow requirements should be calculated on realistic production goals. From Chapter 6, there are five factors to consider:

1 maintenance – which depends on live weight
2 lactation – which depends on the yield and composition of milk
3 pregnancy – which depends on the number of months pregnant
4 activity – which depends on the distance and terrain walked to and from the dairy
5 changes in body reserves – which depends on changes in live weight and/or body condition.

Machine chopping of greenchop maize reduces forage selection (Guizhou province, China).

Minerals and vitamins are necessary to fine-tune the system. Often trace element deficiencies are regional and seasonal. Their variability may depend on forage management. When the basal diet is predominantly improved grass species, most of these problems can be reduced by managing the sward well.

Minerals and vitamins have not been included in the exercises in this chapter, although it is important to know whether deficiencies are present on the farm.

As forages are generally the cheapest feeds (see Chapter 8), the main aim of supplementary feeds is to use them to fill in nutrient gaps that occur due to variations in forage availability and quality. In forage-based systems, the most limiting nutrient for milk production is energy. The poorer quality of tropical forages, compared to temperate forages, means that it they can only provide sufficient energy for low levels of milk production, 7 to 8 L/cow per day, which may also be associated with live weight losses. Excessive live weight losses can impair reproductive performance.

12.1.2 How to formulate a diet

Several worksheets are presented at the end of this chapter. Work sheet 1 is used to calculate the energy, protein and fibre needs of a cow, while Work sheet 2 is used to calculate the energy, protein and fibre content of a diet. Work sheet 3 is used to calculate the cost of energy and protein. These Work sheets are also presented in Appendix 6.

The exercises for this chapter (and in Appendix 6) introduce one way of calculating whether the diet is appropriate for cows to reach their expected lactation and live weight performance.

To fill in the worksheets, reference should be made to tables in Chapter 6 and this chapter, although the relevant tables are duplicated in Appendix 5. A calculator is also required.

12.2 Estimating the limits of feed intake

As well as knowing what the cow needs and what nutrients the feeds can provide, consideration must be given to whether cows can consume that amount of food to provide these nutrients. There are two 'rules of thumb' available for estimating how much cows will eat. It is difficult to measure intake of animals accurately, particularly if they are grazing.

12.2.1 Cow size and feed quality

Milking cows can generally eat 3% of their live weight (LWT) as dry matter (DM) (Target 10 1999). Therefore, a cow weighing 500 kg can consume no more than 15 kg DM/day, while a 450 kg cow can consume no more than 13.5 kg DM/day.

Live weight on its own is not always a good indicator of intake limits for individual animals as cows of the same live weight can differ in appetite, in rumen capacity or in eating habits. Feed of the same quality may be eaten in different amounts, depending on chop length, dry matter content or palatability.

The second rule of thumb is based on the combination of percentage of Neutral

Detergent Fibre (NDF%) and live weight. As percentage of Neutral Detergent Fibre increases in forages, cows eat less according to the following formula:

$$\text{Maximum dry matter intake (kg/d)} = (120 \times \text{NDF\%}) \div (100 \times \text{LWT})$$

The following estimations for daily maximum intake for a diet containing 45% NDF are:

- for 450 kg cows, $(120 \div 45) \div 100 \times 450$ kg = 12.0 kg DM/d
- for 500 kg cows, $(120 \div 45) \div 100 \times 500$ kg = 13.3 kg DM/d

Table 12.1 lists these amounts for various live weight and Neutral Detergent Fibre contents.

Table 12.1 Maximum daily dry matter intake of cows (kg/d) as affected by cow live weight and diet Neutral Detergent Fibre (NDF) content
(Source: Linn and Martin 1989)

Live weight	NDF content (%)											
(kg)	25	30	35	40	45	50	55	60	65	70	75	80
100	4.8	4.0	3.4	3.0	2.7	2.4	2.2	2.0	1.8	1.7	1.6	1.5
150	7.2	6.0	5.1	4.5	4.0	3.6	3.3	3.0	2.8	2.6	2.4	2.3
200	9.6	8.0	6.9	6.0	5.3	4.8	4.4	4.0	3.7	3.4	3.2	3.0
250	12.0	10.0	8.6	7.5	6.7	6.0	5.5	5.0	4.6	4.3	4.0	3.8
300	14.4	12.0	10.3	9.0	8.0	7.2	6.5	6.0	5.5	5.1	4.8	4.5
350	16.8	14.0	12.0	10.5	9.3	8.4	7.6	7.0	6.5	6.0	5.6	5.3
400	19.2	16.0	13.7	12.0	10.7	9.6	8.7	8.0	7.4	6.9	6.4	6.0
450	21.6	18.0	15.4	13.5	12.0	10.8	9.8	9.0	8.3	7.7	7.2	6.8
500	24.0	20.0	17.1	15.0	13.3	12.0	10.9	10.0	9.2	8.6	8.0	7.5
550	26.4	22.0	18.9	16.5	14.7	13.2	12.0	11.0	10.2	9.4	8.8	8.3
600	28.8	24.0	20.6	18.0	16.0	14.4	13.1	12.0	11.1	10.3	9.6	9.0
650	31.2	26.0	22.3	19.5	17.3	15.6	14.2	13.0	12.0	11.1	10.4	9.8

If cows can select within their diets, allowance should probably be made for less fibre in the diet.For example, if the diet on offer tests at 50% NDF, then diet that is selected by the cow may be 5% to 10% lower, or 40% to 45% NDF.

The above rule applies to non-pregnant cows. The capacity of cows in late pregnancy is less because the rumen size is reduced by the increased size of the growing foetus.

Table 12.1 was developed in the United States, from studies conducted in temperate feedlot dairies, and may not be directly applicable to tropical small holder systems. Temperate forages generally have lower levels of fibre than tropical forages. Hence, at similar forage dry matter intakes, cows in South-East Asia would be consuming more fibre than would cows from say, southern Australia. Therefore, at the same live weight, such cows may be able to consume more NDF, hence have a higher maximum dry matter intake, than that predicted from Table 12.1.

To calculate the appetite limit for milking cows taking into account the fibre content of their total diet, the NDF content of each diet constituent must be known. To date, there are no such predictors of appetite restrictions based on Crude Fibre (CF) analyses. Furthermore, it is not possible to calculate Neutral Detergent Fibre from Crude Fibre because these two values measure different components of dietary fibre (see Figure 4.4). Crude Fibre measures alkali-insoluble lignin plus cellulose, whereas Neutral Detergent Fibre measures plant cell walls, which are comprised of alkali-soluble and alkali-insoluble lignin, hemicellulose plus cellulose.

The major (and possibly only) reason for measuring Crude Fibre in feeds is to calculate Total Digestible Nutrients. The newer measurement of Neutral Detergent Fibre is a more meaningful one of dietary fibre, as it quantifies the plant cell walls, which are directly related to digestibility and appetite restrictions.

Table 12.1 is based on dry matter intake of dairy feedlot ratios. Diets containing large amounts of freshly harvested forages may create another problem to milking cows, namely excess moisture content. Wilting fresh tropical forage increases dry matter intake in milking cows (Moran and Mickan 2004). Therefore, Table 12.1 should be considered only a very approximate guide as to the appetite limits of milking cows. It is unlikely that 500 kg milking cows fed good quality tropical pastures/concentrate diets supplying 10 MJ/kg DM of ME would consume more than 13 to 15 kg DM/d. Intake predictions for dry cows and young stock are discussed in the following section.

12.2.2 Examples of intake predictions

Holmes *et al.* (2002) estimated the maximum daily intakes of different classes of dairy stock for forage diets varying in ME content (Table 12.2). These are for grazing animals, so may underestimate intakes in housed animals. Intakes for lactating cows offered diets of less than 9.0 MJ/kg DM of ME are not included in the table because such diets should not be offered to milking cows either at pasture or indoors.

Table 12.2 Maximum intake of forages (kg DM/cow per day) differing in energy content

(Source: Holmes *et al.* 2002)

	Live weight (kg)	Energy content (MJ/kg DM)		
		>10.5	9.0–10.5	7.5–9.0
Heifers	100	2.8	–	–
	200	6.0	4.6	3.5
	300	8.0	6.2	4.5
Dry cows	350	9.0	7.3	5.0
	400	10.0	8.1	5.5
	450	10.9	8.8	6.1
	500	11.9	9.5	6.6
Pregnant cows	350	10.8	9.2	7.9
	400	12.0	10.2	8.8
	450	13.1	11.1	9.6
	500	15.2	12.1	10.4
Lactating cows	350	15.5	12.6	–
	400	16.0	15.0	–
	450	17.6	15.2	–
	500	19.1	16.5	–

Chamberlain and Wilkinson (1996) predicted appetites of milking cows based on their diet quality, live weight and milk yield and these are presented in Table 12.3. These intakes were predicted from the Ministry of Agriculture, Fisheries and Food (1984) and indicate nothing about their adequacy to support milk production. In many cases, intakes are too low for cows to consume sufficient energy and protein, hence they will have to lose weight to achieve the target milk yields.

These feed intakes are predicted for cows more than 12 weeks into their lactation. For cows in their first five weeks of lactation, Chamberlain and Wilkinson (1996) considered their appetites to be only 86%, while from week 6 to 12, appetites will be 95%, of those in Table 12.3.

Table 12.3 Predicted daily intakes (kg DM/cow per day) of different diets in cows of various live weights and milk yields
(Source: Chamberlain and Wilkinson 1996)

Diet [ME] (MJ/kg DM)	Live weight (kg)	Daily milk yield (L/cow)				
		0	5	10	15	20
9.0	400	7.5	8.4	9.2	10.1	10.9
	500	9.4	10.3	11.1	12.0	12.8
	600	11.2	12.0	12.9	13.7	14.6
10.0	400	8.9	9.9	10.9	11.5	12.0
	500	11.1	12.1	13.1	14.0	14.5
	600	13.2	14.2	15.2	16.2	17.0
11.0	400	10.0	10.5	11.0	11.5	12.0
	500	12.5	13.0	13.5	14.0	14.5
	600	15.0	15.5	16.0	16.5	17.0

A simpler predictor of dry matter intake (DMI) uses live weight (LWT) and milk yield (MY) as follows:

$$\text{DMI} = 2.5\%\ \text{LWT} + 10\%\ \text{MY}$$

This equation provides the same predicted intakes as Table 12.3 for diets with 11 MJ/kg DM of Metabolisable Energy (ME), so is less relevant to tropical diets with their lower dietary ME contents.

12.3 Animal production level

Some ration formulation computer programs take into account that high yielding cows are less efficient at using energy than low producing animals. This effect can be quantified by determining the Animal Production Level (APL) which is the total energy requirements divided by the maintenance energy requirements. A correction factor to account for this inefficiency can then be determined (from Table 12.4) and applied to the total energy requirements to calculate the adjusted energy requirements, modified for the higher level of production, be it more milk, increased milk solids, a growing foetus or deposition of body reserves. For every increase in APL above 1.0, the total energy requirements increase by 1.8% (Chamberlain and Wilkinson 1996). This correction factor can be applied to either Total Digestible Nutrients or Metabolisable Energy calculations of energy requirements.

Table 12.4 Relationship between Animal Production Level and Correction Factor to use to adjust total energy requirements
(Source: Chamberlain and Wilkinson 1996)

Animal Production Level	Correction Factor
1.0	1.000
2.0	1.018
3.0	1.036
4.0	1.054
5.0	1.072
1 unit	0.018

To calculate the Animal Production Level (APL), Correction Factor (CFac), and adjusted energy requirements, use the following equations:

$$\text{APL} = \text{Total energy requirements} \div \text{Maintenance energy requirements}$$
$$\text{CFac} = 1 + [(\text{APL} - 1) \times 0.018].$$

Adjusted energy requirements = CFac × Total energy requirements (either kg TDN/d or MJ ME/d).

The Total Digestible Nutrient requirements of seven different cows is calculated in Table 17.3. For each cow, the APL, hence the correction factor, can be applied, as in Table 12.5. In each case, the level of animal production has only increased the total energy requirements by 2% to 3%. Because this adjustment is relatively small, it is rarely used in ration formulation. However, it does quantify the effect of higher feed intake and shorter rumen retention time on reducing feed efficiency.

Table 12.5 Daily energy requirements of cows at different stages of lactation and pregnancy, adjusted for the correction factor for Animal Production Level (see also Table 17.3)
Total Digestible Nutrients (TDN).

Cow details	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6	Cow 7
Description							
Live weight (kg)	550	550	550	550	500	500	500
Month of pregnancy	0	0	0	3rd	6th	7th	9th
Milk production (L/d)	20	17	13	10	8	5	0
Fat test (%)	3.6	3.6	3.6	3.6	4.0	4.0	0
Protein test (%)	3.2	3.2	3.2	3.2	3.8	3.8	0
LW gain/loss (kg/d)	-0.5	0	0	0	0	+0.5	+1.0
Energy requirements							
Maintenance (kg TDN/d)	4.1	4.1	4.1	4.1	3.8	3.8	3.8
Total energy requirements (kg TDN/d)	11.1	10.9	9.3	8.1	7.6	8.0	9.1
Animal Production Level	2.7	2.7	2.3	2.0	2.0	2.1	2.4
Correction factor	1.03	1.03	1.02	1.02	1.02	1.02	1.03
Adjusted energy requirements (kg TDN/d)	11.4	11.2	9.5	8.3	7.8	8.2	9.4

12.4 Formulating a ration

12.4.1 Using the worksheets

To balance a diet, you need to know which nutrients are limiting. These limitations can then be overcome by selecting supplements rich in these nutrients. This is very much trial and error.

1 Use Work sheet 1 to calculate the theoretical ration to satisfy nutrient requirements for a desired level of production.
2 Use Work sheet 2 to determine the nutrients supplied by a particular combination of feeds (basal forage and supplements).
3 Once the limiting nutrients are known, select the most appropriate supplement to balance the diet.
4 The Neutral Detergent Fibre content of the total diet provides a guide to the likelihood of the entire diet being consumed.

12.4.2 Deciding on supplements

Choosing the most economical supplement depends on the deficiency being corrected: whether energy, protein or fibre. For example, if energy is deficient, then choose the feed that provides the most energy at the cheapest price per MJ of ME (or per kg of TDN).

Price per tonne of dry matter can be deceptive. Look at the composition of the dry matter. Prices for wet or as-fed feed are even more deceptive: who wants to pay for water?

To calculate the cost of energy, protein or fibre, the following information is required:

1 nutrient content: dry matter, energy, protein, fibre
2 cost of feed on a fresh weight basis.

Work sheet 3 allows the calculation of the cost per unit of nutrient (ie MJ of ME or kg of Crude Protein, CP). Local Currency Units (LCU) must be used to calculate nutrient costs and these are presented in Appendix 3.

Decisions on what supplements to feed depend on more than just the cost of the feed itself. Increased capital requirements, extra labour and other costs need to be considered when deciding on the supplement to best balance a diet.

Once farmers have invested in equipment to handle by-products, the range of supplements that can be fed increases. The best and most economical feed will vary from farm to farm given the farmer's situation and equipment.

12.5 Computer aids to ration formulation

There is a wide variety of computer models used for ration formulation. Some are relatively simple, requiring the sort of data input described in this manual. Others are more complex, either requiring a more sophisticated data input, or using similar input but deriving additional parameters with which to formulate the diet to achieve target levels of performance.

When using computers, the validity of the formulated ration is only as good as the data available to describe the ration constituents, or as computer specialists say, 'GIGO –

garbage in = garbage out'. For example, if the feed analyses data are derived only from tables, such as those in Chapter 10, and not from actual analyses of feed samples of the ration to be fed, complex computer models may not necessarily improve the ability to predict animal performance accurately from such a formulated ration.

Ration formulation programs using computer software are basically just large calculators. They provide theoretical answers, which fortunately because of the rapidity of the production response to changes in feeding management, can be quickly validated on-farm. Most of the ration formulation computer programs that are commercially available were developed for temperate dairy systems where feeds, herd management and cow genotypes are often vastly different to those encountered in tropical small holder systems. However, as they are based on biological responses to increments in nutrient intakes, such predictions should be equally accurate in all situations. However, it is important to validate these models in such systems, as this is the only way to gain confidence in their usefulness in predicting production responses to a range of feeding scenarios in that system.

This section introduces four computer programs to facilitate the formulation in the tropics of rations for milking cows and young dairy stock.

12.5.1 RUMNUT

The Agricultural Research Council of the United Kingdom (Agricultural Research Council 1984, Ministry of Agriculture, Fisheries and Food 1984) provides one of the major international standards for calculating the nutrient requirements of livestock, such as dairy cattle. RUMNUT is a commercial UK software package based on ARC data, which formulates rations from a large database of dietary ingredients. It is based on temperate feeds but new data on nutritive value of tropical forages, concentrates and by-products can be easily incorporated into the database. RUMNUT will run using either the Metabolisable Energy or Total Digestible Nutrients system for describing energy and it calculates profit as financial margins over all feeds.

The program is relatively simple to use and the suppliers provide good after sales service. RUMNUT is available from Dr Tom Chamberlain at tom@rumnut.com, with further information of the program at www.rumnut.com.

12.5.2 NRC

The National Research Council of the United States provides the second major international standard for calculating the nutrient requirements of livestock, such as dairy cattle. The latest edition of the NRC manual, the 7th (National Research Council 2000), includes a ration formulation program, which is available from the Internet at no cost from www.nap.edu/html/dairymodel/.

This program utilises the entire National Research Council (2000) collection of databases for nutrient requirements of dairy stock and nutrient contents of feeds, allowing the formulation of rations of specified feed mixes for any given level of milk production in cows or growth in young stock. The energy requirements are expressed in TDN units.

12.5.3 DRASTIC

One major problem with formulating rations for livestock in the tropics is the lack of reliable information on the nutritive value of available feeds, compounded with their large variability. This makes routine analyses or reliance on 'book values' of the composition of tropical feeds to be of little practical value. DRASTIC was specifically written to overcome this problem. It is the abbreviation for **D**airy **RA**tioning **S**ystem for the **T**rop**IC**s, a program developed by tropical dairy specialists in the United Kingdom.

DRASTIC uses qualitative and visual indicators of forages that can be easily undertaken by farmers, such as leaf: stem ratio, days after defoliation, forage colour, pest or disease damage, odour, moisture content, length of chop and general assessment. These are related directly to actual measures of energy and protein contents for specific forage species of grasses, legumes, silages and hays/crop residues which are then used to calculate nutrient intakes, to predict cow performance. The program even allows for grazing in predicting forage intakes.

Feeding out pasture silage on a large dairy farm in northern Vietnam.

The program predicts performance from existing rations or formulates rations to meet target milk yields. After inputting ration costs and milk returns, it calculates margin over feed costs for any feeding scenario.

DRASTIC then provides a tool to assist rationing dairy cows where access to technical knowledge is limited but practical experiences are considerable. The program is freely available from Dr Peter Stirling at drastic@stirlingthorne.com or www.stirlingthorne.com/about_drastic.html

12.5.4 KYMILK, KYHEIF and the TDN Workbook

KYMILK is an Excel spreadsheet, written by the author of this manual, that calculates the energy requirements of grazing or housed milking cows based on Agricultural Research Council (1984) standards, either on a daily basis or over various stages of the lactation cycle. It formulates rations and calculates total feed costs. KYHEIF is another EXCEL spreadsheet which calculates energy requirements of young stock, milk-fed calves and growing heifers. A third program, the TDN Workbook, calculates Total Digestible Nutrients and Metabolisable Energy contents of feeds directly from their chemical analyses.

All programs are freely available from the author, Dr John Moran at john.moran@dpi.vic.gov.au.

Work sheet 1: To calculate the daily energy, protein and fibre needs of a cow

The cow	Her energy needs (MJ of ME)	Her protein needs	Her fibre needs
Cow live weight A [ ] kg	For maintenance I [ ] MJ	Early lactation 16–18% Mid-lactation 14–16% Late lactation 12–14% Dry 10–12%	(17% CF or 30% NDF)
Daily activity level Terrain (1–5) B [ ] MJ/km	For activity [ ] From B X [ ] km = J [ ] MJ		
Month of pregnancy D [ ] th month	For pregnancy (Table 6.2) L [ ] MJ		
Daily milk production Volume E [ ] Litres Fat test F [ ] % Protein test G [ ] %	For milk production (Table 6.3) [ ] From E X [ ] MJ/L = M [ ] MJ		
Daily change in body condition gain + loss – H [ ] kg/cow /day	For or from condition (Table 6.5) [ ] From H X [ ] MJ/kg = N [ ] MJ		

Total daily needs of this cow: Energy [ ] MJ I + J + L + M ± N Crude protein [ ] % from above NDF or CF [ ] % from above

Work sheet 2: To calculate the energy, protein and fibre content of a diet

Dry matter	Energy (MJ)	Protein	Fibre
Forage: [ ] kg/cow/day X [ ] Dry matter % ÷100 = **A** [ ]	[ ] from A X [ ] MJ/kg DM = **F** [ ] MJ/cow/day	[ ] from A X [ ] Protein % ÷100 = **J** [ ] kg/cow/day	[ ] from A X [ ] NDF/CF % ÷ 100 = **O** [ ] kg/cow/day
Supplement 1: [ ] kg/cow/day X [ ] Dry matter % ÷100 = **B** [ ] kg DM/cow/day	[ ] from B X [ ] MJ/kg DM = **G** [ ] MJ/cow/day	[ ] from B X [ ] Protein % ÷100 = **K** [ ] kg/cow/day	[ ] from B X [ ] NDF/CF % ÷ 100 = **P** [ ] kg/cow/day
Supplement 2: [ ] kg/cow/day X [ ] Dry matter % ÷100 = **C** [ ] kg DM/cow/day	[ ] from C X [ ] MJ/kg DM = **H** [ ] MJ/cow/day	[ ] from C X [ ] Protein % ÷100 = **L** [ ] kg/cow/day	[ ] from C X [ ] NDF/CF % ÷ 100 = **Q** [ ] kg/cow/day
Supplement 3: [ ] kg/cow/day X [ ] Dry matter % ÷100 = **D** [ ] kg DM/cow/day	[ ] from D X [ ] MJ/kg DM = **I** [ ] MJ/cow/day	[ ] from D X [ ] Protein % ÷100 = **M** [ ] kg/cow/day	[ ] from D X [ ] NDF/CF % ÷ 100 = **R** [ ] kg/cow/day
Total daily dry matter intake **E** [ ] A+B+C+D kg DM/cow	Total daily energy intake [ ] F+G+H+I MJ /cow	Total daily protein intake **N** [ ] J+K+L+M kg/cow	Total daily fibre intake **S** [ ] O+P+Q+R kg/cow
Total daily DM intake limit [ ] kg/cow Use T and Table 12.1 or the formula (120÷T) ÷100 X live weight		Protein % of ration [ ] N÷E X 100	NDF/CF % of ration **T** [ ] S÷E X 100
Cow requirements (from Worksheet 1)	Total daily energy requirement [ ] MJ	Crude protein requirement [ ] %	Fibre requirement [ ] % NDF/CF

Work sheet 3: The cost of nutrients in feeds (local currency units or LCU)

Feed 1:

Cost per kg Dry Matter (DM)

	X		X 100	=	A
kg bought		DM %			kg DM bought

	÷		X 100	=	B
Cost (LCU)		kg DM bought			LCU/kg DM

Cost per MJ of Metabolisable Energy (ME)

	÷			=	C
LCU/kg DM		MJ /kg DM			LCU/MJ of ME

Cost per kg of Crude Protein (CP)

	÷		X 100	=	D
LCU/kg DM		CP %			LCU/kg CP

Feed 2:

Cost per kg DM

	X		÷ 100	=	A
kg bought		DM %			kg DM bought

	÷		X 100	=	B
Cost (LCU)		kg DM bought			LCU/kg DM

Cost per MJ of ME

	X			=	C
LCU/kg DM		MJ /kg DM			LCU/MJ of ME

Cost per kg of CP

	÷		X 100	=	D
LCU/kg DM		CP %			LCU/kg CP

13

Problems with unbalanced diets

This chapter:

Explains why some diets lead to reduced milk yields and metabolic problems.

The main points in this chapter:

- diets should be properly balanced for energy, protein, fibre and certain minerals to ensure optimum cow performance
- examples of metabolic disorders due to dietary problems include milk fever, grass tetany, ketosis and lactic acidosis
- a code of Good Manufacturing Practice (GMP) is presented to minimise potential problems with contamination of prepared animal feeds
- feed buffers stabilise rumen pH and help overcome acidosis
- certain feed additives may be more suited to intensive production rather than small holder dairy systems
- manure consistency is a useful guide when trouble shooting feeding problems
- the on-farm feed safety section of the FAO (2004) guide to good dairy farming practices is presented.

Diets should be properly balanced for energy, protein, fibre and certain minerals to ensure optimum cow performance. This chapter discusses some of the indicators of unbalanced diets and also the major metabolic disorders that can be traced to nutrient deficiencies.

13.1 Some indicators of unbalanced diets

The most important indicators of unbalanced diets can be used to identify dietary problems, while others are listed in Section 13.5.

13.1.1 Lack of rumination

After an initial period of eating forages, animals normally start to ruminate or chew their cud.

If this is not occurring in much of the herd (say 50%), then there may be a lack of fibre in the diet. This may be confirmed by looking for changes in milk composition as described below.

13.1.2 Loose manure

If faecal material is very loose and watery, it may indicate a lack of fibre in the diet. Assessing any changes in milk composition can also check this (see Table 13.2 for a summary of a manure consistency scoring system to assist with balancing diets).

13.1.3 Low milk fat test

A drop in milk fat test tends to occur when the herd is placed on a low fibre diet (eg a diet high in cereal grain and very immature forage).

When the rumen microbes ferment fibre, the resulting end product, acetate, is used to produce milk fat. If the level of fibre in the diet is low, milk fat production decreases.

The easiest way to increase the fibre content of the diet is to feed hay or straw. Take care though when feeding out poor quality forages. A drop in dietary energy intake could cause milk and protein yield to fall.

13.1.4 Low milk protein (or solids-not-fat) test

Low milk protein or Solids-Not-Fat (SNF) content is common in early lactation when cows are in negative energy balance. In other words, their energy needs are greater than their intakes causing them to lose body condition. Shortages of energy reduce protein utilisation by rumen microbes. As a result, the supply of microbial protein, cows' major protein source, is reduced.

Under most circumstances, providing a higher energy diet will lift protein or the solids-not-fat test. Cow will respond to protein supplementation with a lift in protein or the solids-not-fat test only if they are truly deficient in dietary protein. This is because they are unable to utilise energy properly when there is a protein shortfall.

When protein is lacking, microbial growth is depressed. As a result, microbial fermentation is reduced and less energy becomes available. Cows then lose weight to compensate for the lack of dietary energy. When fat is mobilised, values for the milk fat test tends to increase.

13.1.5 Reduced feed intake

Many of the causes are discussed later in this chapter.

13.2 Metabolic disorders and unbalanced diets

Metabolic disorders can be clinical, when there are obvious symptoms, or subclinical, when there are not. Even at the subclinical level, metabolic disorders can depress feed intake and cause production losses.

Metabolic disorders such as ketosis and acidosis are usually linked to low intakes around calving or abrupt changes in diet.

Managing nutrition well during the dry period and in early lactation is the key to preventing or minimising the occurrence of metabolic disorders. The aim is to:

- maximise nutrient intake around calving and in early lactation by providing enough high quality feed
- avoid decreases in intake caused by sudden changes in diet when cows calve and join the milking herd.

Nutritional management at this time also has a major role in minimising milk fever and grass tetany.

13.2.1 Milk fever

Milk fever is caused by a sudden and severe decrease in blood calcium levels at the onset of lactation, due to large increases in demand for calcium for milk production. The incidence of milk fever increases with age and the number of previous lactations.

Cows have mechanisms for adapting to these increased demands for calcium. The mechanisms are:

- increasing the absorption of calcium from the intestine
- mobilising calcium reserves held in bones.

These mechanisms are activated in response to low concentrations of blood calcium. But they take some time to start working following calving. When this process does not happen quickly enough, calcium replenishment into the bloodstream cannot keep pace with the output of calcium in milk. Once calcium levels fall, muscular tremors and paralysis occur, followed by cow collapse and eventually death.

The key to reducing the incidence of milk fever is to stimulate cows' mechanisms for mobilising calcium from the skeleton and increasing absorption from the intestine prior to calving, so that they are 'primed' to meet the increased calcium demands after calving. The following management strategies can be implemented:

- feed diets low in calcium during the dry period – this means restricting fresh pasture (particularly legumes) and providing grass-based hay instead
- alter the cow's Dietary Cation–Anion Balance (DCAB).

Dietary cation–anion balance

The dietary cation–anion balance refers to the balance between positive ions (sodium, potassium) and negative ions (chloride, sulfate). Ideally, negatives should outweigh positives, but this is difficult to achieve in a forage-based system.

Feeding higher levels of negatively charged ions produces a condition called metabolic acidosis. Cows can remove calcium from bone more rapidly when they are affected by metabolic acidosis. Calcium mobilisation is encouraged, thus preparing cows for the increased requirements around calving. To do this, the diet must be higher in anions than cations. This means feeding lower levels of potassium and sodium.

How can the dietary cation–anion balance be managed?

1 **Choose forages carefully**. They can affect the acid–base balance. Some forages are high in potassium (often due to potassium fertilisers). Hays grown on soils with poor fertiliser histories generally contain less potassium.
2 **Feed anionic salts (also called acid salts).** These salts include magnesium sulfate (Epsom salts), ammonium sulfate and ammonium chloride. Some of these salts are quite unpalatable. There are various methods of feeding them, including commercially prepared pelleted supplements. Mixing these salts into molasses to improve palatability is not a good idea, as molasses contains potassium, which, being positively charged, tends to cancel out the effect of feeding the extra negatively charged ions. Anionic salt mixtures should be discontinued after calving.

13.2.2 Grass tetany

Grass tetany or grass staggers often occurs in lactating cows within the first few months after calving. It appears as muscular spasms and convulsions and can eventually cause death. Grass tetany is associated with low magnesium levels in the blood. Since magnesium is not stored in the body, the cow relies on a daily intake of magnesium to meet her needs.

Conditions that reduce magnesium intake or blood magnesium levels and increase the likelihood of grass tetany include:

- feeding grass-dominant rations – these may not supply the magnesium necessary to meet the needs of a cow in early lactation
- topdressing grasses with potash (potassium) or nitrogenous fertilisers, as these can reduce the availability of magnesium to the animal (as potassium and ammonia restrict the absorption of magnesium)
- short periods of fasting which can occur during yarding, transport or exposure to cold, wet, windy weather.

Grass tetany can be prevented by including a magnesium supplement in the diet to provide each cow with 10 to 15 g/d of magnesium. Supplementation should begin one week prior to calving.

Common sources of magnesium are:

- insoluble magnesium oxide (known as causmag) dusted on to hay or added to concentrates at a rate of 50 g/cow per day or dusted on to pasture at a rate of 50 to 75 g/cow per day
- magnesium incorporated into licks
- soluble magnesium sulfate (Epsom salts) at a rate of 50 g/L per cow per day in drinking water or at a rate of 60 g/cow per day in a drench
- soluble magnesium chloride at a rate of 5 g/L per cow/day in drinking water or at a rate of 100 g/cow per day in a drench.

High levels (over 30 g/cow per day) of granulated magnesium oxide have been identified as a common factor in herds which are affected by severe outbreaks of

Salmonella. This needs to be weighed up against the risk of grass tetany. Some veterinarians suggest lowering granulated causmag levels if a *Salmonella* case occurs.

13.2.3 Ketosis or acetonaemia

Ketosis, or acetonaemia, occurs when cows rely heavily on fat reserves for energy during early lactation. It is most common in cows fed low energy diets during early lactation. When there is insufficient energy in the diet, cows draw on body condition to make up the deficit.

Fat reserves contain ketones, a source of energy. Ketones are often used by cows to supplement dietary energy, particularly during early lactation – hence the expression 'milking off her back'. To prevent ketosis, feed a well-balanced diet with enough energy to minimise the reliance on body fat reserves in early lactation. Supplying starchy feeds rich in rapidly fermentable carbohydrates or feeding molasses can reduce the incidence of ketosis.

Ketosis highlights the need to avoid abrupt changes in the diet which may decrease intake in early lactation, and also underlines the importance of maximising nutrient intake with high quality feed during this period.

13.2.4 Lactic acidosis

Under extreme conditions, such as feeding very high levels of starchy supplements, large amounts of lactic acid are formed in the rumen. Acid may be produced faster than it can be absorbed or buffered. When lactic acid continues to build up, the rumen pH decreases (becomes more acidic) and microbial activity slows down. When the microbes stop working, fibre digestion is reduced and voluntary food intake is depressed.

Acidosis can be clinical (with cows obviously sick) when rumen pH falls below 5.0 or subclinical when rumen pH falls below 5.5. Symptoms of subclinical acidosis include:

- low milk fat test, below 3.0% to 3.3%
- low milk protein test
- reduced milk yield
- reduced feed efficiency
- sore feet due to laminitis or overgrown claws (see Chapter 19)
- manure in cows on same diet varying from firm to very liquid (see Table 13.2)
- manure foamy containing gas bubbles
- manure containing larger than normal lengths of undigested fibre, more than 1.2 cm long
- manure containing undigested yet ground grain, less than 3.5 cm in size
- limited rumination, less than 50% of the cows cud chewing while resting
- cyclical feed intakes.

To avoid acidosis, cereal grain should be introduced gradually (ie 0.5 kg grain/cow each day) so that the population of rumen microbes can adjust according to the type of fermentation required (more starch fermenting microbes may be needed). Different cows respond differently to grain feeding. Some cows can handle 6 kg grain/day while others will get sick on 3 kg/day; there is always a cow that will eat more than her fair share. The key to success is to make it a gradual daily increase and to watch the cows and check for symptoms of acidosis (grain poisoning).

Acidosis can be overcome by feeding more fibrous roughages, but that can lead to reduced feed intakes, hence milk yields. Buffers can be included in the diet to stabilise rumen pH so that the rumen environment allows a healthy population of rumen microbes (see Table 13.1).

Feeding management can also influence the incidence of subclinical acidosis in that when cows do not have access to feed when they are hungry, they overeat when they do, having a larger than normal feed when they eventually get access to the feed trough. In this case the acidosis is not caused by lactic acid, but by excess production of the volatile fatty acids from rumen digestion (see Chapters 5 and 14). It is then important that all cows should be able to eat when they want to.

Another symptom of acidosis is sore feet. Farms where cows are less able to lie down, hence spend too long standing, particularly on hard surfaces, can have greater problems with sore feet due to both trauma and acidosis. Cows should be able to lie down for at least eight hours each day. Other factors that can increase problems with sore feet include:

- heat stress (when some cows prefer to stand)
- cows spending too long waiting to be machine milked
- cows with 'perching' behaviour, namely standing with their front feet in the feed trough and their back feet on the floor.

13.2.5 Feed toxicities

Not all animal health problems arise from unbalanced diets. Some feeds contain anti-nutritional factors (Devendra 1992) such as:

- prussic acid (cyanide) in some varieties of forage sorghums, when harvested or grazed as immature crops, or when drought stressed
- hydrocyanic acid in fresh cassava forage
- mimosine in some varieties of Leucaena
- gossypol in whole cottonseed and cottonseed meal
- tannins in banana stems and leaves, mango seed kernel, sal seed meal
- trypsin inhibitor in soybean products.

Mouldy silage can contain bacteria such as *Listeria*, which can cause abortions in dairy cows; it can also pass through the milk and infect humans. Noxious fungi in silage can lead to pneumonia and abortions in cows. Many different coloured moulds can be found in poorly preserved silages, but unfortunately their colour is not a good guide to the type of mould or its toxicity.

The high humidity and temperature of tropical environments encourages the growth of many contaminating microbes. For example, *Fusarium* and *Aspergillus* which produce mycotoxins and aflatoxins can grow on moist cereal grains and by-products. Feed ingredients, of both plant and animal origin, are frequently contaminated with *Salmonella,* which can cause disease and death, particularly in young calves.

In humid tropical countries, veterinary drugs may be administered in animal feeds, some of which have been banned in many Western countries. There can also be potential hazards, to both animal and human health, from excessive levels of herbicides, pesticides and fungicides as well as other industrial or environmental contaminants, such as heavy metals. Many of these compounds can accumulate in animal tissues and be excreted in milk.

The recent human health issues arising from 'mad cow disease' (bovine spongiform encephalopathy) has led to bans in most countries in feeding products from ruminant animals back to ruminants.

Code of Good Manufacturing Practice

The Food and Agriculture Organization of the United Nations (FAO 1997) has developed a code of Good Manufacturing Practice for the preparation of formulated animal feeds based on the following recommendations:

- Buildings and equipment, including processing machinery, should be constructed in a manner which permits ease of operation, maintenance and cleaning.
- Records should be maintained concerning source of ingredients, formulation including details and source of all additives, date of manufacture, processing conditions and any date of dispatch, details of transport and destination.
- Water used in feed manufacture should be of potable (drinkable) quality.
- Machinery coming into contact with feed should be dried following any wet cleaning process.
- Condensation should be minimised.
- Sewage, waste and rain water should be disposed of in a manner that ensures that equipment, ingredients and feed are not contaminated.
- Feed processing plants, storage facilities and their immediate surroundings should be kept clean and free of pests.
- Raw materials of animal and plant origin and mineral supplements, veterinary drugs and other additives should be obtained from reputable sources, preferably with a supplier warranty.
- Equipment should be flushed with clean feed material between batches of different formulations to control cross-contamination.
- Pathogen control procedures, such as pasteurisation or the addition of an organic acid to inhibit mould growth, should be used where appropriate and results monitored.
- Apart from feeds fed moist, such as silage and wet by-products, feed should be kept dry to limit fungal and bacterial growth, which may necessitate ventilation and temperature control.
- Packaging material should be newly manufactured unless known to be free of hazards that might become feedborne.
- Feeds should be delivered and used as soon as possible after manufacture.
- All plant staff should be adequately trained and should work on these standards.

13.3 Buffers

Buffers stabilise rumen pH and help prevent reductions in pH caused by acids produced in the rumen.

Saliva contains sodium bicarbonate and sodium biphosphate, which are both naturally occurring buffers. They neutralise rumen pH, keeping it stable at around pH 6 to 7.

When cows chew their cud (especially in response to fibrous forages) they produce large quantities of saliva (100–150 L of saliva/cow per day). With enough fibre in the diet, saliva production alone can generally maintain rumen pH.

When cows are fed high levels of cereal grains, starch is fermented quickly in the rumen to produce Volatile Fatty Acids (VFAs). The production of volatile fatty acids, especially lactic acid, may be greater than the rate at which they are absorbed or buffered. The resulting decrease in the pH of the rumen (increased acidity) stops other bacteria from digesting fibre. This in turn slows digestion and causes a loss of appetite.

Acidosis can be prevented in diets high in grain and low in roughage or fibre by supplying mineral buffers. Table 13.1 outlines some common buffers and additives used in high grain diets. However, these are not a substitute for fibre, and the fibre content of the diet should be maintained.

Table 13.1 Buffers and additives used in high grain diets

Additive/buffer	Diet DM%	Feeding rate (kg/t grain)	Function
Sodium bicarbonate ($NaHCO_3$)	1.5–2	15–20	Neutralises rumen acids to help prevent digestive upsets. Can be bitter and become unpalatable to stock if more than 4% fed. Tends to absorb moisture and form clumps which should be sieved out before feeding.
Causmag	Up to 1	10	Neutralises rumen acids. Source of magnesium to prevent grass tetany.
Sodium bentonite	Up to 4	Up to 40	Effectiveness as a buffer uncertain. Moderates the digestion of grains in the rumen and prevents cows from eating too much grain.
Crushed limestone	1.5	15	Effectiveness as a buffer uncertain. Useful in high grain diets as a source of calcium and magnesium

13.4 Other feed additives

A feed additive can be described as a feed ingredient that produces a desirable animal response.

Feed additives have gained attention and use in recent years. Expected responses from feed additives include higher milk yields, increases in milk fat and protein contents, improved dry matter intake, a more stable rumen pH and/or improved fibre digestion. These additives may be more suited to intensive production rather than small holder dairy systems.

The primary feed additives currently being used are ionophores and antibiotics. Monensin (sold as Rumensin ®) and lasolocid (sold as Eskalin®) are two commonly used additives which produce their effects by modifying the rumen environment. They alter the microbial population of the rumen, which, in turn, changes the mix of end products from microbial fermentation.

Rumensin® reduces the population of microbes that produce methane gas (which cannot be used by the cow as an energy source). The proportion of microbes that ferment feed to other more useful sources of energy is increased, resulting in improved milk yields. Responses to this additive depend on the diet and the stage of lactation.

Eskalin® inhibits the microbes that produce lactic acid and can, therefore, be important in preventing lactic acidosis.

13.5 Troubleshooting feeding problems

There are many simple observations farmers can use to highlight problems with feeding management. Such quick checks include:

- manure consistency, colour and content (see Table 13.2)
- cows eat all the concentrates on offer
- rumination – ideally 50% of the herd should be ruminating when resting
- hair coat – appearance and cleanliness
- cow's visual appearance – the diet should be reviewed if the cows are looking poor with dull sunken eyes, scruffy coat and hunched backs
- respiration rate, coughing and nasal discharges
- mobility of legs and feet using the locomotion index (see Chapter 19)
- body condition at different stages of lactation, using the scoring system (see Chapter 18)
- physical appearance and smell of forages
- physical appearance and smell of concentrates
- sudden changes in milk yield
- sudden changes in milk composition, namely fat and protein (or solids-non-fat) contents
- metabolic problems (see Section 13.2)
- physical conditions in shed such as cleanliness and ventilation.

A sudden change in one of these quick checks may be due to a temporary fluctuation in nutrition. Provided that the check quickly returns to normal, cow performance may not be adversely affected. Take action when a quick check remains abnormal for several consecutive days or several quick checks become abnormal at the same time.

If whole cereal grains are purchased for processing while formulating the concentrate mix, manure should also be checked for whole grains. Only take note of intact grains, those with starch in the grain, and disregard grain husks. Excessive amounts of intact whole grains in manure indicate inadequate digestion. The likely causes are:

- the grain has not been processed or crushed adequately
- the diet may be deficient in fibre.

Seek nutritional advice to determine the cause of the abnormal manure.

Monitoring manure consistency

Manure that is excessively loose or dry and firm for the diet fed may indicate a dietary imbalance that requires action. Manure pats can be easily evaluated using a 1 to 5 scoring system as described in Table 13.2.

When assessing the herd's average manure score, it is important to assess the range in consistency of faecal pats. If more than 20% are one score or greater (or less) than the average, this may indicate a nutritional imbalance or management problem. With cows living in sheds, the consistency of manure should be made only on faecal pats on clean floors (ie without any urine contamination that will change pat consistency over time).

Table 13.2 Evaluating manure consistency

Score	Manure description	Action required
1	Very liquid manure with consistency of pea soup. May leave cows rectum in a steady flow. Includes cows with diarrhoea	Increase effective fibre intake and seek nutritional advice
2	Runny manure which does not form a distinct plie. Manure will splatter on impact and form lose piles less than 25 mm high	Consider increasing effective fibre intake
3	Manure has porridge-like consistency. Forms a soft pile 40–50 mm high, which may have several concentric rings and a small depression in the middle. Make a plopping sound when it hits concrete floors and will stick to the toes of your shoes.	This is the desired consistency
4	Thick manure, sticks to shoes and readily forms piles more than 50 mm high	Consider reducing effective fibre intake and increasing concentrate intakes. Seek nutritional advice
5	Manure appears as firm faecal balls	Consider reducing effective fibre intake and ensure adequate drinking water is available. Seek nutritional advice

13.6 FAO guide to good dairy farming practice

The FAO, in collaboration with the International Dairy Federation, published a 30-page manual for dairy farmers to support the marketing of safe, quality assured milk and dairy

This 100-day-old Napier grass is very low in nutritive value, even when managed well (Central Java, Indonesia).

products (Food and Agriculture Organization 2004). The focus of the manual is to relate consumer safety and best practice at the farm level to prevent problems occurring rather than solving them once they occur.

There are recommended or Good Agricultural Practices (GAP) for five areas of farm activity:

1 animal health
2 milking hygiene
3 animal feeding and water
4 animal welfare
5 environment.

Oil palm frons are a very poor forage source, even when finely chopped (Malacca, Malaysia).

Table 13.3 summarises those practices specifically related to feeding management in GAP 3 and 4.

Table 13.3 Good practices in farm management related to animal feeding, watering and welfare
(Source: FAO 2004)

Good agricultural practice (GAP)	Examples of suggested measures to achieve GAP	Objectives and control measures
GAP 3. Animals need to be fed and watered with products of suitable quality and safety		
3.1 Ensure animal feed and water are of adequate quality	3.1.1. Ensure the nutritional needs of the animals are met 3.1.2. Ensure good quality water supplies are provided, regularly checked and maintained 3.1.3. Use different equipment for handling chemicals and feed stuffs 3.1.4. Ensure chemicals are used appropriately on pastures and forage crops 3.1.5. Only use approved chemicals for treatment of animal feeds or components of animal feeds and observe withholding periods	– Keeping animals healthy with good quality feed – Preserve water supplies and animal feed materials from chemical contamination – Avoid chemical contamination due to farming practices
3.2 Control storage conditions of feed	3.2.1. Separate feeds intended for different species 3.2.2. Ensure appropriate storage conditions to avoid feed contamination 3.2.3. Reject mouldy feed	– No microbial or toxin contamination or unintended use of prohibited feed ingredients or veterinary preparations – Keeping animals healthy with good quality feed
3.3 Ensure the traceability of feedstuffs bought onto the farm	3.3.1. All suppliers of animal feeds should have an approved quality assurance program in place 3.3.2. Maintain records of all feeds or feed ingredients received on the farm (specified bills or delivery notes on order)	– Quality assurance program of feed supplier
GAP 4. Animals should be kept according to acceptable principles of animal welfare		
4.1 Ensure animals are free from thirst, hunger and malnutrition	4.1.1. Provide sufficient feed (forage and/or fodder) and water every day 4.1.2. Adjust stocking rates and/or supplementary feeding to ensure adequate water, feed and fodder supply 4.1.3. Protect animals from toxic plants and other harmful substances 4.1.4. Provide water supplies of good quality that are regularly checked and maintained	– Healthy, productive animals – Appropriate feeding and watering of animals

14

Diet and milk production

This chapter:

Explains how milk is produced in the udder from the end-products of digestion, how the level of feeding and composition of the diet affects milk volume and composition and how cows partition some of these nutrients into body condition.

The main points in this chapter:

- because of their limited rumen capacity, cows in early lactation require feed with low fibre levels
- high levels of feeding in early lactation will not make up for poor condition at calving. It is important to feed cows well in early lactation, approaching peak lactation and peak intake
- cows close to calving and in early lactation need high quality diets with adequate supplies of energy, protein, fibre and minerals. It is important to avoid abrupt changes to the diet
- diet has considerable influence on the fat and protein content of milk, but relatively little effect on its lactose content
- cows should be in body condition score 4.5 to 5.5 when they calve
- cows put on condition more efficiently in late lactation when they are still milking, rather than when they are dry
- the persistency of milk production throughout lactation, expressed as the monthly percentage decline from peak yield, is a good guide to the feeding management. The target should be 7% to 8% per month.

The ability of cows to produce milk depends largely on:

- water and feed eaten; intakes of dry matter, energy, protein and fibre. The feed must first be digested (broken down to its constituent parts) for the products of digestion to be absorbed into the blood from the digestive tract

- how they use (or partition) these products of digestion for maintenance, activity, pregnancy, milk production or body condition.

This chapter discusses how cows partition nutrients between maintenance, milk production and body condition. Feed intake (the amount and type of feed and the resultant products of digestion) and their use or partitioning of these products to metabolic activities all influence the volume and composition of milk produced.

14.1 Fate of the products of digestion

There are a range of products from the digestion of feeds consumed. These include ammonia, carbon dioxide, methane, Volatile Fatty Acids (VFAs), fats, undigested fibre, rumen microbes and undegradable protein. Some products of digestion are wasted (carbon dioxide, methane, undigested fibre), with most being used by cows. The three major volatile fatty acids produced from rumen digestion are acetic acid (or acetate), propionic acid (or propionate) and butyric acid (or butyrate).

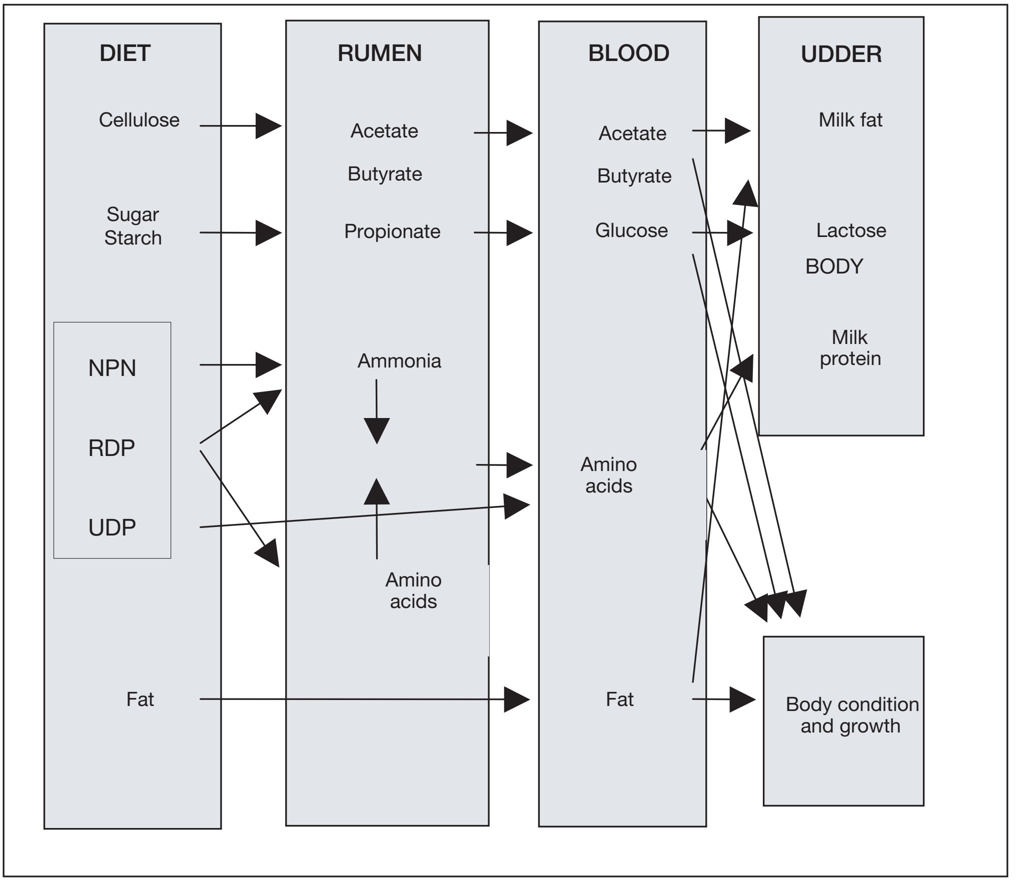


Figure 14.1 Flow of the major nutrients from the diet, through the rumen, to blood, and to the udder or to body condition and growth. Non-protein nitrogen (NPN); Rumen Degradable Protein (RDP); Undegradable Dietary Protein (UDP).

Fats (from acetate, butyrate and fats in the diet), glucose (from propionate), and amino acids (from microbes and undegradable dietary protein), circulate in the blood streams of the cow, becoming available for their role in metabolic processes (Figure 14.1).

14.2 Milk production in the udder

14.2.1 What is milk?

Milk is produced in the mammary gland by the udder tissue. About 500 L of blood pass through the udder to produce 1 L of milk. Blood delivers water, glucose, fats and amino acids to the udder. Cells in the udder tissue use these substrates to form and secrete milk which is made up of:

- water, from water in the blood
- lactose (milk sugar), produced from the glucose (from propionate) in the blood
- milk fat, produced from the fats (from acetate, fats in the diet, and released body fat) in the blood
- milk protein (mostly casein), built from the amino acids (from microbes and Undegradable Dietary Protein, UDP) in the blood (using glucose as an energy source to do the building).

The level of fat and protein in milk varies with many factors such as the breed of cow, stage of lactation, body condition and the diet.

14.2.2 Lactose production in the udder

The udder makes lactose from glucose arriving in the blood. The lactose secreted into the udder attracts water with it, at roughly constant proportions. The lactose content of milk hardly varies, at about 4.8% (Figure 14.2). Therefore, the quantity of glucose arriving at the udder determines how much lactose is produced, hence what volume of milk is produced. This can be depicted as follows:

More blood glucose → More lactose (kg) → More milk (L) → Constant lactose test

Figure 14.2 Relationship between quantity of glucose reaching the udder and volume of milk produced.

14.2.3 Fat production in the udder

The secretory cells in the udder make milk fat from the fats carried in the blood. These blood fats come from acetate and butyrate (mainly from fibre in the diet), from the fat from body condition, or from fats in the diet.

Fat percentage (or test) varies greatly, depending on:

- The type of energy in the diet. Fat test is higher in diets high in fibre, when the blood carries more acetate. Fat test is lower in diets high in starch, because the blood contains more glucose (from the propionate), which is used for lactose

production. On a high starch diet, not only is less milk fat produced, but the extra lactose produced increases the milk volume, diluting the fat even more.
- The stage of lactation. Fat test is likely to be lower in early lactation when milk volume is at its highest
- Body condition of the cow. Fat test is higher in cows losing body condition, which is used for milk fat production. Body condition loss in early lactation (if cows have condition to utilise) may help maintain milk fat concentration as yield increases.
- Energy intake. Fat test tends to be lower if cows are well fed. When energy intakes are high, rumen fermentation rates are also high, the rumen is more acidic (lower pH), and the starch-digesting microbes which produce propionate will work better than the fibre-digesting microbes which produce acetate. With more propionate (which is converted to glucose), there will be more lactose produced and, therefore, a greater volume of milk. With less acetate, there will be less fat.

14.2.4 Protein production in the udder

The udder makes milk protein from the amino acids and glucose carried in the blood. Amino acids are the building blocks, and the glucose provides the energy to do the building.

Sometimes, although the supply of amino acids to the udder is plentiful, there is not enough glucose energy available to build them into milk protein. In this case, some of the amino acids are converted to glucose, and used to provide energy. This is not an efficient use of feed because it wastes the protein-producing potential of the amino acids.

Conversely, if glucose is plentiful but amino acids are in short supply, the building of milk protein will be limited. The surplus glucose may produce some lactose, but most will be stored. Cows will then put on body condition rather than produce more milk. This also is not an efficient use of feed.

Milk protein and lactose production (and hence milk volume) are related because:

- glucose in the blood is needed to produce both lactose and milk protein
- the quantity of amino acids and the amount of glucose in the blood, ready for protein and lactose production, tend to be related to each other due to diet.

A well-balanced diet high in energy often produces more rumen microbes, which are broken down to Undegradable Dietary Protein and amino acids; and a high energy diet also produces more propionate, which converts to glucose. However, a diet higher in fibre often produces fewer microbes and more acetate, which converts to fats. Amino acids can be broken down to glucose if there is a shortage of glucose. The reverse cannot occur.

Usually when milk protein production is high, lactose production is also high. Because lactose is high, milk volume is also high. So, as more kilograms of protein are produced, the number of litres increases, keeping the protein test fairly constant. Therefore, the diet does not greatly affect the protein test and certainly not as much as the diet affects the fat test.

14.2.5 Summarising nutritional effects on milk composition

Table 14.1 presents a summary of some of the effects of feeding management on milk composition. The measures of feeding management are relative to those on a well-balanced diet.

Table 14.1 Effects of feeding management on milk composition

Feeding management	Milk fat	Milk protein
Maximum intake	Increase	+ 0.2 to 0.3% units
Increase grain feeding frequency	+0.2 to 0.3% units	Small increase
Underfeed energy	Little effect	–0.1 to 0.4% units
High fibre	Small increase	–0.1 to 0.4% units
Low fibre	–1.0% units or more	+ 0.2 to 0.3% units
Low protein	No effect	Decrease if marginal
Excess fat	Variable	–0.1 to 0.2% units
Grinding/pelletising of concentrate	–0.1 to 0.2% units	Little effect
Heat stress	Variable	–0.1 to 0.3% units
Restrict water	Increase	Increase
Improving body condition at calving	+0.1 to 0.3% units	Little effect

An innovative small holder dairy farm in Sumatra, Indonesia, with a wilting rack to routinely wilt fresh forages prior to feeding.

Mott grass, an improved variety of Napier grass, has a high leaf to stem ration, hence a high nutritive value (East Java, Indonesia).

14.2.6 How milk composition varies with level of concentrates fed

With intensification of small holder dairying in many peri-urban areas in South-East Asia, shortages in quality roughages have led to increasing amounts of concentrate feeding, often with dramatic effects on milk composition. Sanh (2001) conducted a series of feeding trials in North Vietnam using crossbred Friesian cows fed diets based on varying proportions of Napier grass, brewer's grain and formulated concentrates, based on local by-products such as rice bran, cassava meal, maize bran and groundnut cake. Forage:concentrate ratios varied from 70:30 to 30:70.

When the forage ratio decreased from the highest to lowest, the daily Metabolisable Energy intake increased by 5 to 6 MJ/cow per day at a constant feeding level and by 8 to 13 MJ/cow per day at *ad libitum* feeding. The cows responded with higher daily milk yields with increasing concentrate. In addition, contents of Milk Protein (MP) increased and of Milk Fat (MF) decreased with increasing percentage of concentrates (%C), of which milk fat was more affected than milk protein. The significant regressions were:

Milk fat: MF = 3.90 + 0.006 %C
Milk protein: MP = 3.58 – 0.003 %C

At 30%, 50% and 70% concentrate, fat tests were then 4.1%, 4.2% and 4.3%, respectively, whereas protein tests were 3.5%, 3.4% and 3.4%.

These relationships would vary with base diets as they influence the concentrations of the nutrients presented in Figure 14.1.

14.3 Milk production and body condition

Cow body condition (or the amount of fat that a cow has stored on her body), particularly at calving, has a large effect on milk production and fertility. The cow either stores body fat or mobilises it, depending on the level and type of feed and the stage of lactation. Figure 14.2 depicts the changes during lactation of the partitioning of feed nutrients between the udder and body reserves.

Two hormones, which circulate in the cow's blood, cause body fat to be used or stored:

1. Insulin regulates the storage of body fat from the fats and glucose in the blood. Insulin is produced by the pancreas and is in higher concentrations in the blood when cows are being fed well and glucose is plentiful in the blood.
2. Growth hormone regulates the release of body fat to produce milk fat. Growth hormone is produced by the pituitary gland and is in the blood in higher concentrations in early lactation or when cows are not fed well.

14.3.1 Body condition in early lactation

The ideal body condition score at calving is between 4.5 and 5.5 (see Chapter 18). If cows are fat enough at calving, it is common for one condition score to be taken off the body and used for milk production in the first two months of lactation. This is an important source of energy at a time when cows are trying to achieve peak milk production and their appetites have yet to reach 100% (see Figure 7.1 in Chapter 7).

The amount of energy released when cows lose body condition varies with their live weight. One condition score lost in early lactation can produce up to 220 L of milk, about 10 kg of fat, and about 6.5 kg of protein, over the whole lactation (Robins *et al.* 2003).

If cows are low in body condition at calving and are underfed in early lactation, their peak milk production will be depressed and they will partition less feed to milk and more towards body condition over the whole lactation.

Each improvement in body condition at calving can increase milk yields by up to 1.3 L/d for the first 10 to 15 weeks of lactation with that milk having up to 0.5% higher units of milk fat.

Cows in higher condition at calving also have better fertility. For example, each additional condition score at calving can reduce the time between calving and first heat by 5 to 6 days. Other production benefits to improved body condition are discussed in Chapter 18.

Rapid loss in body condition during early lactation can adversely affect cow performance, through metabolic problems and delayed conception. Substances called 'ketone bodies' are produced as body fat is used. If body condition is being used rapidly, the high level of ketone bodies causes the metabolic disorder called acetonaemia (or ketosis) (see Section 13.2.3 in Chapter 13). Milk production drops suddenly, cows become lethargic and may not even be able to stand. Ketosis is caused by low intakes of energy relative to the requirement for milk production. Increasing the cow's energy intake can prevent ketosis.

14.3.2 Body condition in late lactation and the dry period

Milk production falls in late lactation because:

- cow are using (partitioning) more of their intake to build body condition rather than to produce milk
- their intake ability has decreased
- often, they are being offered less feed or lower quality feed.

Cows with high genetic production potential tend to continue partitioning nutrients to milk rather than to body condition during late lactation. They must then be fed very well at this time to put on body condition ready for their next calving. Consideration could also be given to cease milking very thin cows (dry them off) early, before the recommended 60 days before calving. This will reduce immediate milk returns, but this will be offset by better milk yields and fertility during the next lactation.

The dry period may be the only opportunity for cows to put on condition. However, cows use feed energy more efficiently to put on body condition while still milking compared to when dry. Therefore, it is better to plan feeding management to replace body condition during late lactation, rather than the during the dry period.

14.3.3 Summary of milk production and body condition

- cows should calve between condition scores 4.5 and 5.5 to ensure they have enough body fat to use in early lactation while feed intake lags behind milk production.

- adequate body reserves enable high production peaks to be achieved, which contributes to high milk production for the whole lactation.
- cows need to be well fed throughout the lactation to replace lost body condition.
- cows are more efficient at putting on body condition while still milking.

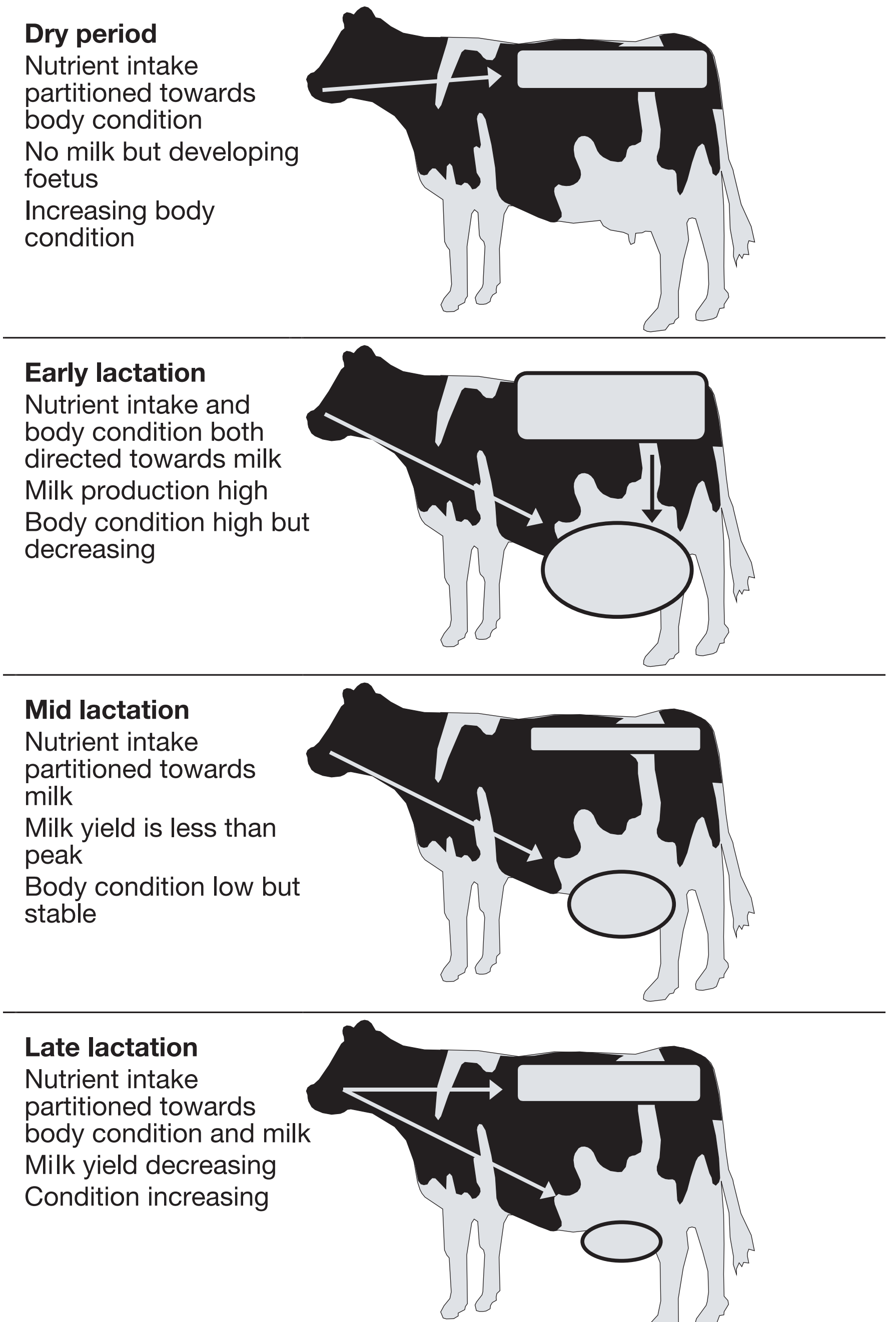


Figure 14.3 Changes in partitioning of feed nutrients over the lactation cycle. (Source: Tyndall, pers comm)

14.4 Persistency of milk production throughout lactation

The various stages of the lactation cycle have been described in Chapter 7. The two major factors determining total lactation yield are peak lactation and the rate of decline from this peak. In temperate dairy systems, total milk yield for a 300-day lactation can be estimated by multiplying peak yield by 200.

Hence, a cow that peaks in milk production at 20 L/d should produce 4000 L/lactation, while a peak of 30 L/d equates to a 6000 L full lactation milk yield. This is based on a rate of decline of 7% to 8% per month from peak yield; that is, every month the cow produces, on average, 7% to 8% of peak yield less than in the previous month. This level of persistency is the target for well-managed, pasture-based herds in temperate regions. Actual values can vary from 3% to 4% per month in fully fed, lot-fed cows to 12% or more per month in very poorly fed cows (eg during a severe dry season following a good wet season in the tropics).

The rate of decline from peak, or persistency, depends on:

- peak milk yield
- nutrient intake following peak yield due to changes in both feed quality and the amount offered
- body condition at calving
- other factors such as disease status and climatic stress.

Generally, the higher the milk yield at peak, the lower its persistency in percentage terms. Underfeeding of cows immediately post-calving reduces peak yield but also has adverse effects on persistency and fertility. Dairy cows have been bred to utilise body reserves for additional milk production, but high rates of live weight loss will delay the onset of oestrus (see Chapter 15). Compared to temperate forages, the lower energy and protein and higher water and fibre contents of tropical forages reduce appetite for forages, thus requiring higher intakes of high quality concentrates to compensate. Underfeeding of high genetic merit cows in early lactation is one of the biggest nutritionally induced problems facing many small holder farmers in the humid tropics.

This problem is induced because cow quality has been overemphasised in many South-East Asian dairy industries without the necessary improvements in feeding systems to utilise this genetic potential. If imported high genetic quality cows are not well fed, milk production is compromised, but of more importance, they will not cycle until many months post-calving.

Thin cows have less body reserves, therefore cannot partition as much to milk yield, thus reducing peak yield and persistency. Unhealthy and heat-stressed cows have reduced appetites, hence poorer persistency of lactation.

14.4.1 Theoretical models of lactation persistency

Data for milk yield over 300-day lactations in cows with various peak milk yields and lactation persistencies are presented in Table 14.2 and Figure 14.3. Such data provide the basis of herd management guidelines for temperate dairy systems with 12-month calving intervals. Depending on herd fertility, hence target lactation lengths, similar guidelines could be developed for 15- or 18-month calving intervals.

Table 14.2 and Figure 14.3 only present data for cows with peak yields of 15, 20 and 25 L milk/day. Small holder dairy farms in the humid tropics with good feeding and herd management should be able to achieve 15 L/d peak yield, and for those with high genetic merit cows, 20 or 25 L/d is realistic. Lactation persistencies of less than 8% per month may be achievable in tropical dairy feedlots but more realistic persistencies are the 10% to 12% per month presented.

Table 14.2 Effect of peak milk yield and persistency on 300 d lactation yields

Peak yield (L/d)	Persistency (%/mth)	Monthly milk decline (L/d)	Full lactation yield (L)	Average daily milk yield over entire lactation (L/d)
15	8	1.2	2980	9.9
	10	1.5	2650	8.9
	12	1.8	2330	7.8
20	8	1.6	3970	13.2
	10	2.0	3540	11.8
	12	2.4	3110	10.4
25	8	2.0	4960	16.6
	10	2.5	4420	14.8
	12	3.0	3885	13.0

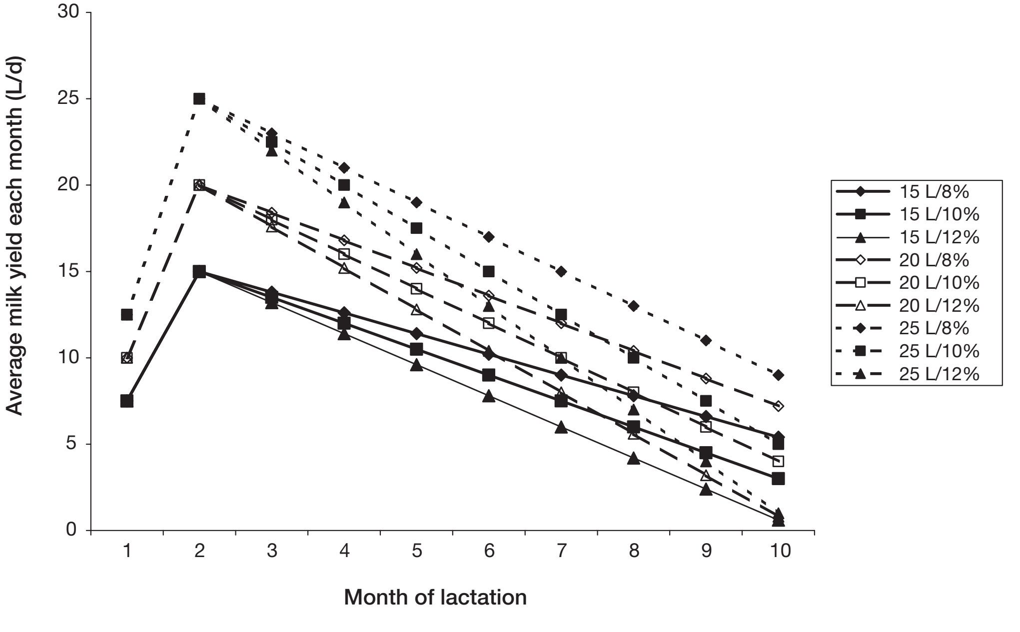


Figure 14.4 Milk yields each month for cows varying in peak yield and persistency. Legend shows peak yield (L/d) and persistency (% decline/mth).

Virtually every small holder farmer records daily milk yield of his cows, so they know peak yield and can easily determine the monthly rate of decline from the peak in litres per day (L/d), hence the percentage decline. This then provides a simple monitoring tool to assess their level of feeding management.

Unless feeding management can be improved, it may be better in the long run to import cows of lower genetic merit. For example, importers may request '5000 L cows' (ie cows that peak at 5000 L under good feeding management, with a persistency of 8%/mth). If, through poor feeding, their persistency is reduced to 12% per month, 300-d lactation yields are only 3900 L and they do not cycle for many months after calving, '4000 L cows' may be a better investment. From Table 14.2, such cows would produce similar milk yields if they could be fed to 8% per month milk persistency and they are more likely to cycle earlier (see Chapter 19).

14.4.2 Effects of diet on lactation persistency

A study in North Vietnam, with mature Friesian × Vietnamese Local Yellow cows weighing 400 kg post-calving, assessed the influence of diet on persistency during early and mid lactation (Sanh 2001). Cows were allocated one of three diets over early lactation (weeks 9–16) (see below) and then again during mid lactation (weeks 17–24) (Table 14.3).

Table 14.3 Effect of feed intake (H is high, M is medium and L is low) on milk production and lactation persistency during early and mid lactation

dry matter intake (DMI); * Persistency is the average rate of decline in milk yield over each 8 week period, expressed as % decline/month. Early lactation (weeks 9–16); mid (weeks 17–24). (Source: Sanh 2001)

Level of intake	H/H		M/M		L/L	
Stage of lactation	Early	Mid	Early	Mid	Early	Mid
Total DMI (kg/cow/day)	11.1	10.6	10.2	9.7	9.3	8.6
Milk yield (L/cow/day)	11.1	9.7	10.8	9.0	10.1	7.4
Persistency (% decline/month)*	2.9	7.4	5.1	10.2	10.6	14.3
Persistency (% decline/month)	5.1		7.6		12.4	
Live weight change (kg/cow per day)	+0.28		+0.18		–0.03	
Days from calving to 1st oestrus	92		94		102	

The diets consisted of the same quantity of freshly harvested Napier grass (4.5–4.7 kg DM/cow per day) with differing amounts of brewers grain and formulated concentrate (50% rice bran, 20% cassava meal, 15% maize bran, 15% groundnut cake). The Napier grass was harvested every 50 to 60 days and contained 19% DM, 11% CP and 9.3 MJ/kg DM of ME. The brewer's grain contained 22% DM, 33% CP and 12.4 MJ/kg DM of ME, and the formulated concentrate 89% DM, 15% CP and 11.5 MJ/kg DM of ME.

During the two stages of lactation, the diets were fed at three levels of intake, high (H), medium (M) and low (L), to supply 110%, 100% and 90%, respectively of National Research Council (1989) requirements. Diets were formulated, based on live weight and daily milk yield, at the beginning of each experimental period. The proportion of Napier grass varied from 40% to 55% on a dry matter basis, and all could be considered good quality lactation diets providing 10.5 to 11.0 MJ/kg DM of ME and 16 to 17% CP.

Two additional treatments are not included in Table 14.3. During early/mid lactation, other cows were fed the H/L and L/H treatments. During mid lactation, the L/H fed and H/L fed cows averaged 8.7 L and 8.5 L of milk/cow day with lactation persistencies of 3.9% and 15.7% decline per month, respectively. There were no effects of any of the feeding levels on milk fat or protein levels. Increased feeding regime increased live weight gain during the 16-week study, while it also had a slight effect on days to first oestrus.

Sanh (2001) considered that these crossbred cows would peak at about 12 L/cow per day under the M feeding regime while he recorded lactation persistencies during early/mid lactation varying from 5% to 8% to 12% decline/month, depending on intake. The highest dry matter intakes (on the H diet) were only 2.7 kg/100 kg LWT. Furthermore, the relatively rapid decline in persistency between early and mid lactation, together with their weight gain during early lactation, on the H and M diets, suggests:

- the genetic merit of these particular cows was not high in that they were not partitioning energy towards milk production during early lactation, or
- presentation of the diet limited nutrient intake, possibly through low dry matter contents, which were only 24 to 27%. Wilting the grass prior to feeding would encourage the cows to consume more.

15

Nutrition and fertility

This chapter:

Explains the effect of both nutritional and non-nutritional factors on the reproductive performance of the dairy herd.

The main points in this chapter:

- how to calculate submission rate and conception rate and use them to describe a herd's reproductive performance
- nutrition is only one of many factors affecting reproduction
- low energy intakes in early lactation can delay the first detected heat and depress the rates of submission and conception
- cows will inevitably be in negative energy balance in early lactation, but good reproductive performance depends on cows:
  – calving in good condition (score 4.5–5.5)
  – reducing the drop in appetite after calving
  – reducing the rate of body condition loss during early lactation, to less than one condition score.

So far in this manual, feeding strategies have focused primarily on achieving optimum milk production. However, to achieve higher production per cow through better management, better genetics and better nutrition, other aspects of cow performance must also be considered. One of the most important of these is fertility or reproductive performance.

Improved reproductive performance provides many benefits to farmers, such as:

- higher average milk yields each day. Cows with poor reproductive performance will spend more of their time in late lactation, when daily milk yields are lower
- fewer cows that have become excessively fat because they have failed to conceive

- less compulsory culling of cows failing to become pregnant
- reduced insemination and semen costs
- heifers calving at a younger age
- increased number of calves produced each year, thus providing more animals for sale or as replacements for the milking herd
- more efficient feed utilisation as a result of the above benefits
- more profits, less work and less worry.

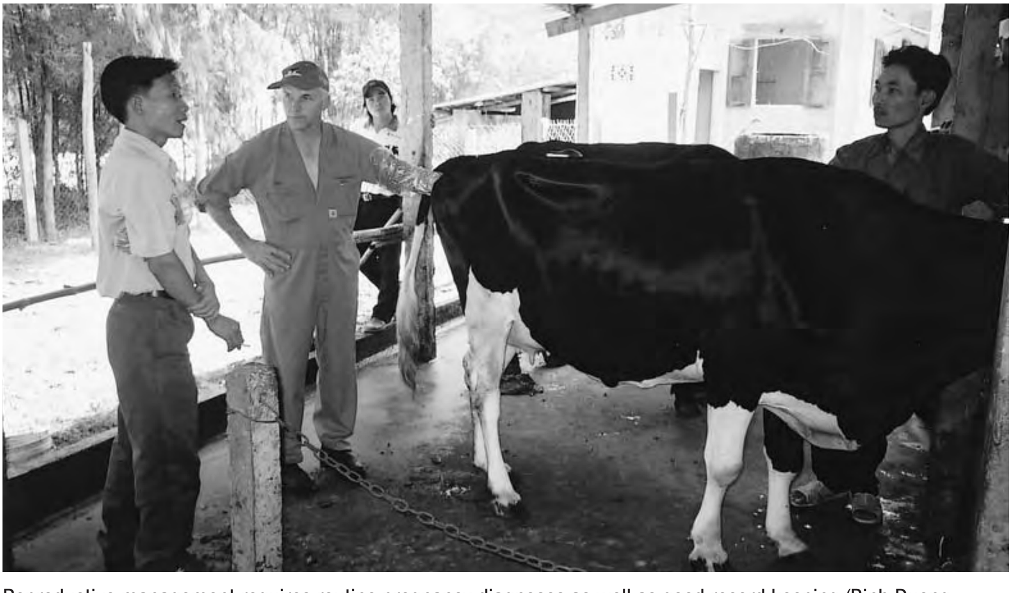
This chapter discusses some of the ways that nutrition affects fertility. Before discussing the effects of nutrition on reproductive performance, reproductive performance needs to be quantified.

15.1 Measures of reproductive performance

For year-round calving herds, there are two useful measures of reproductive performance. These are:

- 100-day in-calf rate. This calculates the percentage of the cows in the herd that become pregnant by 100 days after calving. It also describes how many cows will calve within about 13 months of their previous calving.
- 200-day not-in-calf rate. This calculates the percentage of cows not pregnant by 200 days after calving. Farmers want as many cows as possible to calve within 15 to 16 months after their previous calving.

To calculate these two measures of reproductive performance, one must know accurately when cows become pregnant. It is best to base this on pregnancy testing when cows are between 5 and 15 weeks pregnant. To achieve this, a herd pregnancy testing routine is necessary. Cows not returning to service should be examined on the next



Reproductive management requires routine pregnancy diagnoses as well as good record keeping (Binh Duong province, Vietnam).

pregnancy testing day until they are confirmed pregnant. Pregnancy testing cows every one to two months allows most accurate monitoring.

Two other measures are frequently used to describe reproductive performance. These are average calving to conception interval (or days open) and intercalving interval. These measures are not ideal because there are three major problems with their use:

- They are only averages and do not indicate how many cows actually had long calving to conception intervals. Such problem cows require attention.
- They do not take into account cows that do not become pregnant at all. Obviously these non-pregnant cows are also problem cows.
- These measures can include cows that are routinely inseminated many months after calving, such as high producing cows, which are normally culled as non-fertile.

Submission rates

The submission rate is the percentage of the herd which received at least one insemination within a specified number of days after calving.

To achieve a high 100-day in-calf rate, a high percentage of cows in the herd must be submitted to insemination without undue delay after calving. The 80-day submission rate is the percentage of cows that receive at least one insemination by 80 days after calving.

Conception rates

Conception rates are the numbers of services resulting in pregnancy divided by the total number of services.

This describes the percentage of inseminations that are successful and result in pregnancy. This has always been considered an important measure of reproduction but it does not fully describe overall herd performance. Herds can have high conception rates but poor 100-day in-calf and high 200 day not in-calf rates because of very low 80 day submission rates. Sometimes the first insemination conception rate is calculated by including only the first services after calving in the analyses.

Conception rate is only one aspect of reproduction because herd performance is also dramatically affected by:

- time from calving to first insemination
- percentage of returns to service that are detected
- high levels of reproductive performance can be achieved with only moderate conception rates when submission rates are high and a high percentage of returns to service is detected.

Data from Australian dairy farm surveys can provide a guide to actual and achievable reproductive performance in year-round calving herds. These are presented in Table 15.1.

Table 15.1 Achievable measures of reproductive performance in year-round calving herds (Source: Morton *et al.* 2003)

Measures of reproductive performance	Seek help	Top farmers achieve
100 day in-calf rate	<45%	58%
200 day not-in-calf rate	>19%	13%
80-day submission rate	<61%	73%
Conception rate	<43%	51%

High submission rates are essential for high 100-day in-calf rates.

This large-scale Australian study identified six factors which have large influences on herd reproductive performance. Three are non-nutritional and three are nutritional. They are:

- The length of the voluntary waiting period (ie the number of days delay after calving before farmers begin inseminations). This is 50 to 55 days in the herds with the best fertility.
- Heat detection. Farmers can make two types of mistakes: they can diagnose heat in cows not on heat (called a false positive) or miss a heat identification (undetected heat). Missed heats are more common. The higher the heat detection rate, the higher the submission rate. Farmers with over 80% heat detection rates had 73% 80-day submission rates.
- Artificial insemination (AI) practices. There are many skills in AI, but discussion of these is outside the scope of this manual. Good first insemination rates were 45 to 48%.
- Body condition. Cows calving at condition scores of 4.5 to 5.5 (where 1 = emaciated and 8 = extremely fat, see Chapter 18) had higher 100-day in-calf rates (54%) than those calving at less than 4.5 (41%). Cows calving in very high score (6.0 or more) may lose condition more rapidly after calving and can suffer reduced fertility.
- Feed intake. Better fed cows have higher fertility. Better feeding can improve 100 day in-calf rate from 41% to 57% and reduce 200 day not in-calf rate from 15% to 9%.
- Heifer live weight. The occurrence of the first oestrus in yearlings depends on live weight. Therefore, better feeding practices in early life will lead to younger age at first calving in virgin heifers. These heavier animals will also cycle earlier after calving.

15.2 Non-nutritional factors that affect reproductive performance

Reproductive performance is affected by many factors. Nutrition is only one possible cause of poor reproductive performance. In some herds, nutrition is not the most important cause of poor performance. Some of the other causes can be divided into those that affect submission rate and those that affect conception rate.

The many factors affecting submission and conception rates in tropical small holder herds are listed in Table 15.2, categorised into:

- difficult to influence (generally outside farmers control)
- possible to influence (require some management skills and/or capital)
- easy to influence (require little management skill and/or capital).

It is easier to improve submission rates than conception rates. For example, submission rate may be increased from 40% to 80% with careful management, whereas conception rates may only improve from 30% to 45%. Many of those factors influencing submission but not conception rates are behavioural, such as decreasing the length of the voluntary waiting period and making more effort to improve heat detection.

Table 15.2. Factors affecting submission and conception rates with artificial insemination (or *natural mating*) in tropical small holder herds
(Source; Moran and Tranter 2004)

Ease of influencing	Submission rate (Cows being submitted for insemination *or mating*)	Conception rate (Services per conception)
Difficult Outside farmer control	Mineral deficiencies (defining what minerals)	Semen quality Infectious diseases (requiring government support) Mineral deficiencies (defining what minerals)
Possible Requires some management skills and/or capital	Heat stress Genotype × environment interactions Feeding to cows potential Genetic tendencies for lactation anoestrus Support of infrastructure (eg facilities)	Semen handling AI technique Heat stress
Easy Requires little management skill and/or capital	Deferral of insemination or voluntary waiting period Heat detection Age Heifer size (and age) at first calving *Bull performance* *Bull:cow ratio* Body condition at calving Body condition loss after calving Induced calvings Post-calving nutrition (energy, protein, fibre) Health problems Uterine infections Lameness Retained foetal membranes Milk fever Cystic ovaries	Timing of insemination *Bull fertility* Body condition at calving Body condition loss after calving Post-calving nutrition (energy, protein, fibre) Diseases affecting fertility Uterine infections Other diseases

Heat detection in tropical herds using artificial insemination only

Observations of oestrus are more difficult in the tropics due to anoestrus resulting from poor nutrition and/or intensive suckling. Furthermore, the oestrus period is shorter (10 to 12 hr), signs are less pronounced or mainly shown at night (in buffaloes or local cattle) when farmers are less keen on, or active in, heat detection.

For practical purposes, most small holders use Artificial Insemination (AI) rather than natural mating. This introduces another set of factors limiting herd fertility. Cows tied up in a stall can hardly express the most easily recognisable signs of oestrus like mounting and being mounted.

Cows show signs of heat when they:

- are 18 to 24 d after their last heat (if they are still non pregnant)
- stand to be mounted
- attempt to mount other cows
- are restless and bellow
- have reduced feed intake
- have poor milk let down

- have stringy mucus exuding from their vulva
- have a red and swelling vulva (locally known in Vietnam as 'redneck').

The average duration of heat is about 14 h in normal weather. Heats can be as short as 2 h and as long as 28 h. Observations twice per day are then essential to catch short heats. Observations in the cool of early morning are more likely to detect heat than those in the hotter parts of the day.

The best conception rates occur following insemination 4 to 12 h after the first signs of heat are observed. However, the problem is knowing at what stage of oestrus the particular heat was first detected.

Heat detection can be improved with:

- routine night observations
- interpreting cow behaviour
- checking records for days since previous heat (for closer observation)
- using heat detection aids in larger herds, although tail paint is a cheap effective aid for most farmers
- using oestrus synchronisation as a management aid.

Small holder farmers who continually tether their cows are disadvantaged because cows cannot move around to show the easiest to interpret behavioural signs of heat. Having a small yard in which to let the cows out, say before milking, will aid detection. Using heat aids, such as tail paint or heat mount detectors, can improve detection rates. Vasectomised bulls or hormone treated steers running with the mating herd are also useful in larger herds. Heat synchronisation can offer efficient use of labour as the work of heat detection and artificial insemination is shortened into planned, intensive periods.

Each month farmers need to identify cows which have calved more than 80 days before, but have not been detected on heat, and examine them. This is important if more than 60% of the herd are in this category. Some of these cows may have had an undetected heat, whereas others may not have been on heat and can be treated as non-cycling cows. If most of these cows are in low body condition, their feeding management should be improved. Others may be suffering disorders such as cystic ovaries, infected uterus, and lameness, thus requiring veterinary attention.

Other important factors should be taken into account, such as:

- body condition, too fat or too thin
- rapid loss in body condition
- small heifer size
- diagnosed health problems, such as cystic ovaries, uterine infections, lameness
- heat stress, as apparent from observed high respiration rates and/or high temperature humidity index (see Chapter 19 and Appendix 1).

Assuming heat can be detected early, the message must be passed on to and be acted on by the AI technician. Most dairy cooperatives have a simple and effective system of communication between farmers and AI technicians. Assuming the technician can reach the cow in good time for insemination, the factors listed above are relevant.

15.3 Nutritional factors that affect reproductive performance

15.3.1 Energy intakes and balance

Energy intake affects milk production, body condition and live weight. Numerous studies have investigated effects of milk production, body condition score and live weight on fertility. Results have varied widely. To date, the effects of energy intake on fertility are not fully understood.

Nevertheless, some effects are clear. The effects of energy intake can be separated into effects on submission rates and effects on conception rates.

Effects of energy intake on submission rate

Table 15.3 presents the effect of extreme undernutrition on the onset of cycling. Cows of various breeds were calved in condition scores ranging from 3 to 6 (see Chapter 18) and were then fed 7, 11 or 15 kg DM/day of pasture for the first 5 weeks of lactation. After that, all groups were allocated the same amount of pasture.

Table 15.3 Effect of condition score at calving and post calving feeding on days from calving to first detected heat
(Source: Grainger et al. 1982)

Pasture fed after calving (kg DM /day)	Days from calving to first detected heat			
	Body condition score at calving			
	3	4	5	6
7	55	49	43	38
11	50	44	39	33
15	46	40	34	28

The first detected heat was markedly delayed among cows in poor condition at calving and cows fed very limited pasture after calving. Because of this delay, submission rates were dramatically reduced in the thin and underfed groups. The study in Table 15.3 assesses the effects of nutrition at the low end of the scale. Large, high-producing Holstein-Friesian cows can consume over 20 kg DM/d. It is likely that the cows in this study would have eaten well over 15 kg DM if they had been allowed. So underfeeding was occurring, even in the best-fed groups in the study.

At the other extreme, cows can be too fat at calving. Cows calving in condition scores above 6 are at greater risk of fatty liver syndrome, with associated reduction in appetite, excessive weight loss and increased likelihood of retained foetal membranes and/or non-cycling. Except for some cows being carried over, grazing cows in Australia are rarely seen in condition scores greater than 6. If low-producing cows are fed better both before and after calving, submission and conception rates are improved, as are milk yields.

Extensive work is now focusing on the effects of nutrition in high-producing cows. Probably the best current explanation of the causes of delayed cycling among high-producing cows comes from North America. Under the systems of management there, it appears that condition loss after calving is more likely to cause delayed cycling than is the level of milk production in early lactation.

The problem, as discussed in Chapter 7, is that milk production peaks before maximum feed intake, even where cows are fed *ad libitum*. Therefore in early lactation, cows' energy requirements exceed their intakes. They are in 'negative energy balance' and so they lose body condition and weight. This is seen as the trough that occurs soon after calving (Figure 15.1). In this study, cows lost condition for the first seven weeks of lactation.

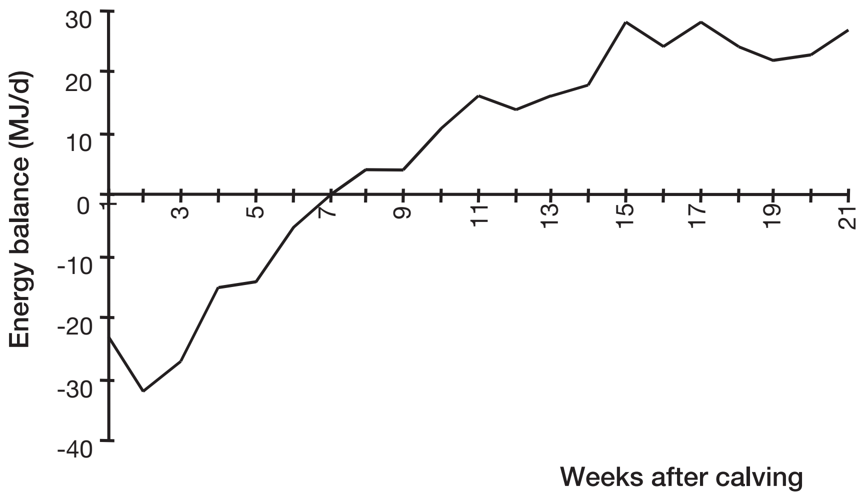


Figure 15.1 Changes in energy balance (in MJ/d) in early and mid-lactation. (Source: Ferguson 1991)

The negative energy balance is worst in the first few weeks after calving, before slow improvement. Intake capacity steadily increases and cows eventually move into positive energy balance. When in positive energy balance, cows began to gain condition.

How does this affect reproductive performance? Some research suggests that cows have their first ovulation about 10 days after the greatest negative energy balance, that is a week or so following their greatest rate of live weight loss. So if the negative energy balance is prolonged, first ovulation will be delayed and submission rates reduced.

Greater negative energy balance (a deeper trough in Figure 15.1) may also cause longer delays to first ovulation. This graph is the average for the group of 40 cows. Clearly some herds will have deeper and more prolonged troughs than others, due to cow type and management.

Importantly, there is also a lot of variation between cows within herds. Higher producing cows will generally have deeper and more prolonged troughs than lower producing cows.

However, the cows with the deepest troughs may not be the highest producers within a herd. Cow appetite can also have large effects. Cows producing a little less but eating a lot less will clearly be at more risk. This effect may be particularly important in forage-based production systems where cows must compete for limited feed.

Effects of energy intake on conception rates

Energy intake and condition score affect onset of cycling after calving. Early onset of cycling clearly increases submission rates. Furthermore, early onset of cycling increases conception rates.

New Zealand research suggests that conception rates are improved in cows, which have had at least one heat before mating (Table 15.4). This is regardless of the length of time between calving and the start of mating.

Table 15.4 Effect of pre-mating heats on first service conception rates
(Source: Macmillan and Clayton 1980)

Number of pre-mating heats	First service conception rate		
	Days from calving to first service		
	40 or more	30–39	Less than 30
0	59	42	32
1	65	49	39
2	67	51	40

Hormonal changes may explain the positive effect of a heat before mating on conception. It appears that high levels of the hormone progesterone in the 12 days before insemination improve conception rates.

The ovary produces progesterone after a cow has ovulated. Cows inseminated on their second ovulation will usually have had much higher progesterone levels for the previous 12 days.

There may also be other explanations for the improvement in conception rates among cows having a heat before mating.

Other effects of energy intake on conception rates

Energy balance may also affect conception rates in other ways. Negative energy balance long before insemination may reduce conception rates. In the ovary, egg development begins around 60 to 100 days before the heat where the egg is released. It may be that adverse conditions around that time can result in a defective egg being produced and released.

If true, this might mean that severe weight loss in early lactation could result in poor quality eggs when cows are inseminated. For late-calving cows, which are mated soon after calving, weight loss in the dry period could have similar effects.

15.3.2 Some implications for management

Management in late lactation

Good herd managers aim to dry off cows in the condition in which they want them to calve. How cows are fed in late lactation and when they are dried off will have huge effects on condition score at drying off and at calving.

Dry cow management

Dry cows must not lose weight. Even if live weight does not seem to be declining, cows may still be losing condition. The increasing weight of the foetus and udder during pregnancy may mask losses of the cow's own body weight.

Cows with higher condition at calving have better fertility. For example, each additional condition score can reduce the time between calving and first feed by five to six days.

Management during the transition period

Decrease in appetite around calving has to be minimised. The cow's rumen needs time to adjust to the new diet. Digestion and intake can be reduced while the rumen is adjusting. This adjustment can start before calving.

In herds where milkers are fed moderate to large quantities of grains, lead feeding (gradual introduction of grain in the diet before calving) helps reduce the impact of dramatic change in diet. Lead feeding may also help retain condition in the last few weeks before calving. Anionic ('acid') salts may enable some forages to be fed to cows due to calve without increasing the risk of milk fever (see Section 13.2.1). Feeding some pasture may help reduce the impact of the dietary changes after calving.

Minimise condition loss after calving

It is crucial to achieve high-energy intakes quickly after calving. The many considerations in feeding cows in early lactation are discussed in other sections of this manual.

15.3.3 Protein intakes

Excess protein

Some diets may lead to the protein content of total diet exceeding cows' requirements. The excess can reduce reproductive performance.

Most of the protein in forages is Rumen Degradable Protein (RDP). Research suggests that diets high in Rumen Degradable Protein depress conception rates. Imbalance between the amounts of fermentable carbohydrate and protein in the diet are the key concern.

Diets with excess protein have effects other than on conception rates. It costs the cow energy to break down the excess protein, energy that could otherwise have been used for milk production and body condition. So, adverse effects of high protein diets on fertility may be due to an energy deficit.

Protein deficiency

The cow's highest requirement for protein is in early lactation. Requirements for both Rumen Degradable Protein and Undegradable Dietary Protein (UDP) increase after calving, especially among high producing cows.

Many of the diets fed throughout South-East (SE) Asia do not provide sufficient protein. This can also reduce reproductive performance.

15.3.4 Intakes of minerals, trace elements and vitamins

Cows require numerous minerals, trace elements and vitamins to survive. The roles of minerals and vitamins have been discussed in Appendix 4, so only those implicated in fertility are mentioned here.

Calcium

Subclinical calcium deficiency in cows around calving can result in calving troubles, retained foetal membranes and inappetence. If correct, these effects could result in reduced reproductive performance.

If either milk fever or subclinical calcium deficiency is considered to be a problem, anionic salts could be used together with other dry cow management strategies. Cows due to calve should not be fed supplements containing sodium bicarbonate.

Magnesium

Supplementary magnesium fed to calving cows reduces the risk of grass tetany. It also reduces the incidence of milk fever. Some advisers recommend feeding supplementary magnesium to avoid subclinical calcium and magnesium deficiencies in cows at calving.

Phosphorus

Phosphorus deficiency has been shown to cause delayed onset of heat in some studies but not others. Phosphorus-deficient cattle can also be energy-deficient in some circumstances (eg during prolonged periods of underfeeding). In these situations, effects of phosphorus deficiency cannot be readily determined.

In early lactation, phosphorus supplied in the many forages is insufficient to meet cows' requirements. Affected cows then use their bone reserves of phosphorus. This may be sufficient to prevent reproductive performance being affected.

Selenium

There are numerous reports of retained foetal membranes due to selenium deficiency.

Detecting deficiencies

Laboratory tests are available for many minerals and trace elements. Although some tests are useful, the results of other tests are not highly correlated with responses to treatment. In other words, even if testing indicates a deficiency, supplementation does not always produce an improvement in animal performance.

Feed analyses might help to estimate an animal's current intake of certain elements, but there are some drawbacks:

- results will vary between feed batches and even between fields on the same farm
- grazing cows select their forage, so sampling has to mimic this in order to estimate what is actually being eaten
- feed intake has to be estimated
- minerals interact with each other – requirements for most minerals and trace elements depend on the amount of other minerals and trace elements present
- meaningful interpretation of feed analyses for minerals and trace elements is not simple.

16

Nutrition and young stock

This chapter:

Explains the nutritional needs of heifers in their three phases of development – milk-fed calf, weaned calf and yearling.

The main points in this chapter:

- a system of heifer rearing should produce healthy animals that are able to grow to target live weight with minimum input costs
- calves must consume at least 4 L of high quality colostrum in their first six hours of life; calves must be hand-fed colostrum if they cannot suckle
- calves should be fed to promote rumen development using high quality concentrates plus limited roughages
- calves can be weaned by six weeks of age if they are eating 0.75 kg concentrates per day
- young calves cannot eat enough forage to sustain good growth rates – forages alone are not suitable for milk-fed calves or for weaned calves until they reach 200 kg live weight
- good heifer growth rates are important for milk production and fertility and to minimise calving difficulties – growth rate in Friesians after weaning should average 0.6 to 0.7 kg/d
- growth should be monitored regularly (preferably by weighing) to ensure that targets are being met
- forages should be high quality (11 MJ/kg DM of ME) if used as the sole food for heifers less than 12 months of age
- forages should be supplemented with concentrates when heifer growth rates fall below 0.5 kg/d.

Well-grown dairy heifers are a good investment in the milking herd. To ensure they grow to become productive and efficient dairy cows, their management must be carefully planned and begin the day they are born.

A well-managed heifer rearing system aims for:

- good animal performance with minimal disease and mortality
- optimum growth rates to achieve target live weights
- minimum costs of inputs, such as feed (milk, concentrates, forages), animal health needs (veterinary fees, drugs) and other operating costs (milk-feeding equipment) to achieve well-reared heifers
- minimum labour requirements
- maximum utilisation of existing facilities such as sheds for rearing and quality forages for feeding.

There is no single best way to milk-rear calves. All sorts of combinations of feeding, housing and husbandry can be successful in the right hands and on the right farm. Successful calf rearing is a specialist job requiring suitable facilities. It also requires a genuine concern for the welfare of young calves and quick responses to early symptoms of disease. If farmers are unable to commit the time and resources to rearing their own replacement heifers, they should seriously consider paying someone who is better placed to do a good job. The establishment of cow colonies (see Section 11.4.3 in Chapter 11) and the sharing of resources of farmers supplying a single dairy cooperative provide the opportunity for a specialist calf and heifer rearer to milk rear and grow out the replacement stock for many farmers.

The first three months are the most expensive period in the life of any dairy cow. During that time, mortality rates are high, up to 10% in many cases. Calves need protection from the extremes of sun, wind and rain no matter what the rearing system. Disease prevention and treatment can be costly during early life.

16.1 Rearing the milk-fed calf

With their undeveloped digestive tract, calves require the highest quality and the most easily digestible source of nutrients: whole milk or milk replacers. Unfortunately, these are also the most expensive feeds. The most effective way of minimising the high feed costs of calf rearing is through early weaning and reduced milk feeding.

The essence of good calf rearing depends on two major nutritional factors. First, an adequate intake of high quality colostrum within the first day of life and, second, feeding management to encourage early rumen development.

16.1.1 Colostrum feeding

Newborn calves are very susceptible to disease. Before they can develop their own immunity they are entirely dependent on the antibodies contained in their mother's milk. It is therefore vital that they receive adequate quantities of antibody-rich colostrum from their mothers or from other freshly calved cows.

Calves should have access to 4 L of colostrum within the first six hours of life. They will not need any additional milk for the next 12 to 24 hr. Any calf that is suspected of not having suckled in the first 3 to 6 hr should be hand-fed the colostrum. With sick or weak calves, colostrum may have to be administered by stomach tube. It is not difficult to stomach-tube young calves.

Frozen colostrum (which can be stored for 18 months) can be thawed out and used, or colostrum from a mature cow within the herd can be fed. Fresh colostrum can be refrigerated for 7 to 10 d. Ideally, colostrum should be tested for antibody concentration to ensure it is of sufficient quality to store.

The level of immunity passed on by the cow increases with her age, since older animals have been exposed to a greater range of infectious organisms to which they have developed antibodies.

Replacement heifers born to first calving cows may require additional stored colostrum from older cows to ensure they develop good disease immunity. Vaccinating cows prior to calving for *Escherichia coli*, *Clostridia* and *Salmonella* can enhance the immune properties of colostrum.

The longer calves spend with their dams, the greater their chances of contracting disease. Therefore, newborn calves should be separated from their dams as quickly as is practically possible.

16.1.2 Early rumen development

The rumen is non-functional in newborn calves, hence, all digestion must take place in the abomasum (or true stomach) and the small intestine. The weaned calf needs a fully functional rumen in order to be well adapted to a forage-based diet. Before weaning, it is important to promote rumen development, so as to avoid growth checks when calves are weaned.

Rumen development occurs through the digestion or fermentation of feeds (roughages and concentrates) by the rumen microbes. Calves should be encouraged to eat solid feeds at an early age, mainly through limiting their access to milk to 4 L/d. From the first week, roughage such as clean straw should be offered in combination with high-quality concentrates specially formulated for rearing calves.

Fresh forages are not good sources of roughage for milk-fed calves. Such forages contain too little fibre, and their very high water content prevents high intakes of feed energy in each mouthful. This limits the feed energy available for rapidly growing animals. Until their rumen capacity is larger, young calves just cannot eat enough fresh forage to sustain high growth rates.

16.2 A successful early weaning recipe for calf rearing

Dairy farmers generally want to feed their calves on the best quality feeds to give the calves a good start to life. However, most farmers feed too much milk for too long.

By continuing to feed milk longer than is necessary, farmers often feed 400 to 500 L of milk (or its equivalent in milk replacer solution) to each calf. They need only feed 200 L of milk or less. Furthermore, much of this milk can be colostrum from calving cows, making the milk feeding costs very low.

If calves are strong, healthy and kept warm and dry, they can be successfully reared on once daily feeding with 4 L of whole milk, or its equivalent in milk replacer. All calves should be offered a specially formulated calf meal from one week of age. Milking cow concentrate formulations do not contain sufficient protein to meet the needs of young calves.

Calves should have limited access to fresh forages. The key to this rearing system is giving the calves continuous access to clean straw as a source of roughage. Note this is clean straw, not good quality pasture hay or lucerne hay.

All calves must be given the opportunity to nibble on the straw even though they will eat very little of it. Straw will encourage rumen development rather than provide nutrients.

If better quality hay is fed in place of straw, calves will eat more roughage but at the expense of concentrate consumption. If good quality hay is fed, it should be limited to 100 to 200 g/calf per day. Clean drinking water must be available at all times.

Feeding milk only once each day helps the calves to develop an appetite for the concentrates. It is the concentrate rather than the milk that should provide the bulk of nutrients to keep the calf growing. Calves can be weaned off milk once they are consuming 0.75 kg/d of concentrates for two or three consecutive days. This usually occurs by about 6 to 8 weeks of age.

Provided calves are eating 0.75 kg/d of concentrates, milk feeding does not have to be reduced gradually. Calves should continue to be housed indoors during weaning.

This system rears the rumen rather than the calf. Systems that involve feeding more milk do not encourage early rumen development and hence calves must be older before they can continue to grow without milk.

It is important that each calf drinks its allocation of milk. Lower milk intakes will limit calf performance because of the inability of the young animal to compensate by eating more concentrates. As well as reducing growth rates, underfed calves may be more susceptible to diseases and other stresses during life. Higher milk intakes will discourage concentrate consumption.

Ideally, calves should be housed individually or in small groups. They should also be individually bucket-fed. There is no advantage in milk feeding using teats rather than buckets; it only creates extra work in keeping them clean.

Weaning age

The age when milk is no longer fed should depend on the quality of feeds available. For example, Ibrahim (1988) suggested calves should be weaned at:

- 2 months, when quantity and quality of roughage and concentrates are good
- 4 months, when quantity and quality of roughage and concentrates are average
- 6 months, when quantity and quality of roughage and concentrates are poor
- 8 months, when suckling and cows are dried off.

Provided they are not adversely affected by disease or very poor feeding management, the growth rates of calves up to weaning is far less of an issue than their performance post-weaning. Prior to weaning calves are fed milk, which contains all the essential nutrients for healthy growth, whereas after weaning the quality and amount of dry feeds has the biggest influence on calf performance. Invariably farmers save their best quality feeds for their milking cows, meaning that young stock suffer from poor feeding management. Weaning programs developed for young stock in temperate regions, where feed quality is usually better, then require close scrutiny to ensure they will still allow weaned stock to achieve their target growth rates (see Section 16.4.1).

Concentrate quality

Milk-fed and weaned calves require concentrates containing higher protein levels (18–20%) than do milking cows (16%). Low protein concentrates will not promote the same rate of rumen and body development in milk fed calves. Consequently two months may be too young for weaning such calves.

Throughout South-East Asia, most formulated supplements for milking cows are formulated to 16% CP, even though on closer investigation (J Moran unpublished 2003), they are frequently below this content. For convenience, many small holder dairy farmers also feed these concentrates to their young stock. Such formulations are far from ideal because of the higher protein requirements of young stock. Depending on the quality of the basal roughage fed post-weaning, 18% may even be insufficient for the concentrates.

Very rarely can small holder farmers purchase higher protein formulated concentrates. In many cases these farmers are not aware of the benefits for their young stock in supplementing available milking concentrates with additional protein supplements.

High protein concentrates may be available, but at great expense, as they have been formulated for pig and poultry incorporating high quality protein ingredients. It would be ideal if a few large scale feed mills, either owned by dairy cooperatives or agribusiness, could formulate calf and heifer mixes with higher protein contents, utilising better quality energy sources and additional minerals and vitamins for optimal growth of young stock. Compared to the higher demand of concentrates specially formulated for milking cows, the formulation of smaller batches of calf/heifer mixes would not be cost effective for small dairy cooperatives.

16.3 Management of weaned replacement heifers

All too often, farmers rear their heifer calves carefully until weaning but neglect them thereafter. Calves that are poorly managed after weaning are disadvantaged for their entire life. Even if they are well fed after mating, their ultimate mature size is restricted and if they do put on extra weight, it tends to be fat. Most of the growth in skeletal size occurs before, not after, puberty.

Weaned heifers do, however, require less attention than milk-fed calves and milking cows. Dairy heifers need to be well fed between weaning and first calving. If growth rates are not maintained, heifers will not reach their target live weights for mating and first calving.

Undersized heifers have more calving difficulties, produce less milk and have greater difficulty getting back into calf during their first lactation. When lactating, they compete poorly with older, bigger cows for feed. Because they are still growing, they use feed for growth rather than for producing milk. Many studies have demonstrated the benefits of well-grown heifers in terms of fertility, milk production and longevity.

16.3.1 Fertility

The onset of puberty, and commencement of cycling, is related to live weight more than to age. A delay in puberty means later conception. All heifers should achieve their target weight before joining, because lighter heifers have lower conception rates. Calving problems depend more on heifer live weights at mating, than on live weights or body condition at calving. Frame size is determined early, so there is doubtful merit in the practice of feeding older heifers to make up for poor growth earlier in life.

Friesian heifers mated below 260 kg had 34% conception to first insemination compared to 58% for heifers mated weighing 300 kg or more. Of the smaller heifers, 24% had difficult calvings. This declined to 8% in heifers mated at 260 to 280 kg and was lowest in 340 to 360 kg heifers. Heifers underweight at mating required considerable assistance if in difficulty during calving.

16.3.2 Milk production

Increasing calving Live Weights (LWT) for Friesians from 360 to 460 kg increased milk production during the first lactation by 400 L (Freeman 1993). This production benefit extended into both the second lactation, with an extra 830 L/extra 100 kg LWT, and the third lactation, with an extra 840 L/extra 100 kg live weight. Heifers calving 100 kg heavier can increase their peak production by 5 L/d during the first lactation.

However, there is little point in rearing well-grown heifers then underfeeding them during their first lactation. Bigger heifers have higher maintenance requirements, which must be met before additional nutrients produce milk. Therefore, good heifer rearing systems should be considered only after feeding systems for milking cows have been developed. Many South-East Asian small holder farmers do not feed their cows well enough to justify producing bigger heifers.

16.3.3 Heifer wastage

Poorly grown heifers do not last long in the milking herd. They are more likely to be culled for poor milk yield or poor fertility during their first lactation.

Total herd costs can be greatly increased by this high rate of wastage. Producers should aim to lose (through deaths or culling) no more than 20% of their replacement heifers between weaning and their second lactation.

16.4 Targets for replacement heifers

16.4.1 Live weight

Traditional target weights are too low to ensure first lactation heifers achieve their productivity potential, particularly on farms where milking cows are well fed. Recommended live weights for Friesian and Jersey heifers at various ages are summarised in Table 16.1. Targets for Zebu or local breed heifers would be similar to those for Jerseys.

Puberty occurs in dairy heifers at 35% to 45% of mature weight, while conception can occur at 45% to 50% of mature weight. A dairy cow will attain her mature live weight in about the fourth lactation and the objective of rearing heifers is to produce an animal 80% to 85% of mature live weight by first calving. Wither height sticks or chest girth tapes are an alternative to scales but they are not as accurate and tend to overestimate live weights.

Table 16.1 Target weights for Friesian and Jersey heifers at different ages
(Source: Moran 2002)

Age (months)	Friesian live weight (kg)	Jersey live weight (kg)
2–3 (weaning)	90–110	65–85
12	250–270	200–230
15 (mating)	300–350	250–275
24 (pre-calving)	500–520	380–410

16.4.2 Wither height

Wither height (or height at the shoulder) is a good measure of bone growth and frame size in heifers. Frame size can influence ease of calving and appetite of milking cows. Farmers should aim for wither heights in Friesians of 123 to 125 cm at 15 m and 133 to 135 cm at 24 m. Corresponding wither heights in Jerseys (and Zebus) are 110 to 112 cm at 15 m and 120 to 122 cm at 24 m.

16.4.3 Age of teeth eruption

It is easy to estimate the approximate age of a heifer by inspecting the state of her teeth. A calf may be born without teeth with the temporary cheek teeth erupting within a few days and the temporary incisor teeth within two weeks.

The age at which the pairs of permanent incisor teeth erupt is as follows:

- first incisor teeth 18 to 24 months
- second incisor teeth 24 to 30 months
- third incisor teeth 36 months
- fourth incisor teeth 40 to 48 months

The permanent cheek teeth erupt between 6 and 36 months, but are harder to identify than the incisor teeth. The age of eruption permanent incisor teeth can vary with feeding regime.

This is a very useful guide when objectively assessing the feeding management of young stock because poorly fed heifers may look healthy and relatively well grown, but if their first (or even second) incisor teeth have erupted they are likely to be much older than at first glance.

The author John Moran, checking the age of heifers from the eruption of their incisor teeth (Central Java, Indonesia).

16.5 Energy and protein requirements for heifers

Table 16.2 shows the energy requirements (for maintenance and growth) of heifers growing at different rates at various live weights. The growth rates for 500 kg heifers assume a contribution of 0.4 kg/d from the growing foetus.

Table 16.2 Energy and protein requirements for growing heifers
(Source: National Research Council 1989)

Live weight (kg)	Energy requirement MJ ME or (*kg TDN/day*) Growth rate (kg/day)				Crude protein (%)
	0.4	0.5	0.6	0.7	
100	28 *(1.8)*	30 *(2.0)*	33 *(2.2)*	36 *(2.4)*	17
200	42 *(2.8)*	45 *(3.0)*	48 *(3.2)*	51 *(3.4)*	16
300	50 *(3.3)*	60 *(4.0)*	64 *(4.2)*	68 *(4.5)*	15
400	75 *(4.9)*	79 *(5.2)*	84 *(5.5)*	89 *(5.9)*	13
500	91 *(6.0)*	95 *(6.3)*	99 *(6.5)*	103 *(6.8)*	13

Growing heifers require a constant source of protein for optimum bone and muscle growth. Table 16.2 also lists crude protein requirements at different live weights.

16.6 Feeding heifers to achieve target live weights

Recommendations for grazing and feeding systems will differ between regions. Rather than depend on recipes, producers should regularly weigh their young stock, then vary feeding strategies according to their growth rates. Growth should average 0.6 to 0.7 kg/d, although that can vary between 0.5 and 1.0 kg/d, depending on available pasture and the supply and cost of suitable supplements.

As fresh forage is the cheapest feed, it should constitute the bulk of the diet, with hay, silage or concentrates used to overcome forage shortages. Fresh forages or conserved hay or silage must be of sufficient quality (at least 10 MJ of ME or 64% Total Digestible Nutrients, TDN) to satisfy the requirements for growth and maintenance.

Until calves reach 200 kg in weight, they are not able to maintain the growth rates needed to reach target weights on diets of either average quality forages or even top quality silage. Their capacity is limited and they simply cannot eat enough dry matter from the forages to meet their nutrient requirements for rapid growth. Forages must be good quality (at least 11 MJ of ME or 70% TDN) if used as the sole feed for heifers less than 12 months of age.

Forage quality and allocation should allow for continuous growth throughout the first two years. Uniform growth is not necessary and may be impracticable with seasonality of quality forage supplies. Yearling heifers have some ability for compensatory gain following periods of mild undernutrition, so long as they have not been grossly underfed. However, heifers should not be allowed to lose weight or to grow very slowly for long periods of time (ie no more than one month).

Ideally growing heifers should be continuously fed concentrates to supplement the fresh forage, the quantity offered depending on target growth rates and the nutrients provided from the forage.

17

Economics of feeding dairy cows

This chapter:

Explains the economic benefits of better feeding that can be easily quantified as the milk income less feed costs.

Presents full economic analyses of small holder dairy systems in Thailand and Vietnam.

The main points in this chapter:

- milk income is derived from milk volume and unit price, both of which can increase with improved feeding management
- feed costs make up 50% to 60% of total farm day-to-day costs on small holder dairy farms
- knowing the nutritive values and units costs of feeds allows decisions to be made on the cheapest way to provide the nutrients to achieve target milk yields
- during the dry season, the use of rice straw to supplement limited forage supplies can seriously affect milk yields by restricting appetites due to high dietary fibre levels
- the energetic efficiency of producing the same volume of milk with fewer cows is enhanced by having fewer cows to feed when dry and having to rear fewer heifer replacements
- this benefit is in addition to the higher milk income less feed costs arising from improved feeding practices
- unit returns from milk can be increased through improving milk composition (by increasing milk solids content) and milk quality (by reducing contamination following milk harvest)
- managing non-productive stock on dairy farms is a major cost, comprising over 40% of total farm cost of milk production.

17.1 The business of dairy farming

All dairy farmers milk cows to make money. Throughout South-East Asia, modern small holder dairy farming is a business and should be treated as such. Farmers should make farm management decisions based on their ultimate profitability. Understanding the principles of feeding dairy cows is only part of their occupation. Their most important occupation is converting this knowledge into money.

When small holder dairying first developed in South-East Asia, the primary motivation for government support was social welfare. Milk production is highly labour intensive, thus providing many employment opportunities, not only on the farm, but also in transporting and processing of milk. Furthermore, farmers could enter the industry with few resources. In countries like Indonesia, up to 20% of the small holders do not own land and they harvest their forage along the roadsides and the banks of rice paddies. They repay the purchase cost of concentrates out of their milk returns and can even source livestock on credit, repaying cooperatives with newly born replacement stock rather than actual cash. Nowadays, many government sponsored programs of social welfare and rural development are being replaced by those aimed at improving farm business management.

Dairy farmers need to develop many new skills to become successful business managers. Not only must they able to budget their cash inputs to match their cash returns during the different seasons of the year, but also they must be able to invest wisely in improving their cattle housing and feeding systems. The availability and quality of dry season forage supplies is generally the major limiting factor to increased farm milk production and profitability, and this should be addressed in any farm development program. Every effort should be made to ensure a reliable supply of quality forages to supplement their wet season forages during the dry season. For example, dairy farmers may consider contracting nearby cropping farmers to grow whole crop maize for silage, then store it in a pit near the milking cows, rather than continue to depend on rice straw and other low quality forages as the major dry season feed.

17.2 Defining 'milk income less feed costs'

One of the primary skills of dairy farm business management is to be able to quantify the day-to-day profits from correct feeding practices. Feed costs make up 50% to 60% of the entire variable (or the day-to-day) costs in small holder dairying, so are an important contributor to the overall cost of production.

A useful measure of the economics of feed management is 'milk income less feed cost' (MIFC). This quantifies the margin available to cover all other costs and leave a profit. It can be defined as:

$$\text{MIFC} = (\text{income from milk sales}) \text{ less } (\text{total feed costs})$$

Where,:

$$\text{milk income} = \text{milk volume (L)} \times \text{unit price in local currency/L}$$

Milk income: this can be influenced in several ways and these have been covered in previous chapters of this manual. First, milk volume increases with better feeding practices. Second, in many regions, unit price increases with improved milk composition, that is, producing milk, which contains more milk fat and/or protein. This again is the result of providing additional feed nutrients, mainly through increasing milk protein contents. Reducing the bacterial contamination, or improving milk quality, can also increase unit price.

Total feed costs: is the total money spent on feeding milking cows, on a daily basis. It does not take into account the costs of feeding dry cows and young stock, although these are part of the total dairy feed costs because every milking cow must spend part of her life as a growing heifer or a dry cow.

Total feed costs are for all the feed consumed, both forages and concentrates. Much of the forage may be home grown, but it still has a cost. There are many definitions about the cost of home-grown forages, but the simplest definition is its 'opportunity cost' or what it would cost to purchase directly from another farmer.

The end point of profitable ration formulation is to formulate a ration to satisfy the nutrient requirements of the animal to achieve a target level of production over a certain time period (day, month or year), at the minimum feed cost. This is called a 'least cost ration' and is used routinely by commercial feed mills to formulate concentrate mixtures to certain specifications based on their cheapest ingredients. In this case, the concentrate mixture is usually formulated using computers, because it only involves a series of simple calculations. Computer programs are also used to develop least cost rations in intensive animal production units, such as piggeries or beef cattle feedlots, where the nutrient requirements have been fully documented. Computer aids to ration formulation have been discussed in Chapter 12. Effectively we will do the same in this chapter, but our 'computer' is the human brain.

This chapter presents a series of case studies for small holder dairy farmers. They are examples of the types of decision-making processes possible once you have some knowledge about cow requirements, the nutritional value of available feeds and their costs. There are many ways in which such information can be used in dairy farm business management, for example deciding when to purchase feeds that vary in cost throughout the year.

Because cows are herbivores, production rations should be based on feeding as much good quality forage as possible, then supplementing with concentrates. Ideally, the unit cost of the forage reduces as more of it is grown to feed the milking herd. That is certainly the case with grazing herds in Australia, although it may not always occur on all small holder farms in South-East Asia.

17.3 Case studies of small holder dairy farmers

17.3.1 Introduction to case studies

This section contains three case studies for small holder farmers in Thailand. The unit of energy is then Total Digestible Nutrients (TDN) and the unit of currency the Thai Bhat. Appendix 3 presents the unit of currency in other South-East Asian countries, together with their relative values in February 2005. The feed costs in the following tables should not just simply be converted from Baht into the currency of the country of interest because their relative purchase (or grown) values will depend on the market forces in that particular country.

For example, Tables 8.1 and 8.2 in Chapter 8 present feed and nutrient costs in Thailand and Vietnam. Compared to the energy sourced from home-grown forages, the energy costs from formulated concentrates are two to three times higher in Thailand but are three to four times higher in Vietnam.

This Thai farmer has a wide variety of feeds available (see Table 17.1) for his herd of milking cows, all at different stages of their lactation cycle. Cows then differ in their levels of milk production and milk composition and their pregnancy status. The forages range from good quality (immature grass and legume, maize silage) through to very poor quality (rice straw). The concentrates range from formulated to high energy (cassava chips) and high protein (cottonseed meal).

The farmer in this example has purchased maize silage, not maize stover silage. Maize grain is the major contributor of energy, so the farmer has decided to invest in the maize including the cob, not just the stover. Maize stover silage would obviously be cheaper, but its nutritive value would also be much lower.

The nutritive values of the feeds, presented in Table 17.1, are 'typical' values for dry matter (DM), Crude Protein (CP), Crude Fibre (CF) and Neutral Detergent Fibre (NDF) and energy (Total Digestible Nutrients, TDN, and Metabolisable Energy, ME) based on the tables presented in Chapter 10. The cost of the energy and protein contained in all these feeds is presented in Table 17.2. The cheapest energy source is cassava chips (and mature grass), while the most expensive is maize silage. The cheapest protein source is cottonseed meal and the most expensive is cassava chips.

Table 17.1 Nutritive values and price of feeds available to the small holder dairy farmer in Thailand
Thai baht (Bt), dry matter (DM); Crude Protein (CP); Crude Fibre (CF); Neutral Detergent Fibre (NDF); and energy Total Digestible Nitrogen (TDN); Metabolisable Energy (ME).

Feed	Price (Bt/kg)	DM (%)	CP (%)	CF (%)	NDF (%)	TDN (%)	ME (MJ/kg DM)
Forages							
Immature grass	0.8	20	10	30	55	60	9.2
Mature grass	0.6	30	8	35	70	50	7.4
Legume	1.0	25	20	32	65	55	8.3
Maize silage	1.5	28	8	24	50	65	10.1
Rice straw	2.5	90	4	42	75	45	6.4
Concentrates							
Formulated concentrate	5.0	90	18	15	25	75	12.0
Maize grain	4.0	85	10	7	8	80	12.9
Cassava chips	2.8	88	2	3	20	80	12.9
Rice bran Gr A	4.5	90	14	13	25	70	11.1
Cottonseed meal	5.2	90	45	13	35	75	12.0

The costs of specific feed nutrients (Table 17.2) can be calculated using Work sheet 3 from Chapter 12.

If the profitability of dairy feeding systems was based only on the cost of feed nutrients, ration formulation would be a relatively simple exercise. However, this is not the case, because ration formulation requires cows to be fed the correct balance of nutrients to produce milk, before nutrient costs can be considered. Not only must diets provide sufficient energy and protein, but fibre levels must not be too high (see Chapter 12).

Table 17.2 Costs of energy and protein in feeds available to the small holder dairy farmer in Thailand
dry matter (DM); Crude Protein (CP); Neutral Detergent Fibre (NDF); and energy, Total Digestible Nitrogen (TDN); Metabolisable Energy (ME)

Feed	Feed cost (Bt/kg)	DM cost (Bt/kg)	Energy cost (Bt/kg TDN)	Protein cost (Bt/kg CP)
Forages				
Immature grass	0.8	4.0	6.7	40
Mature grass	0.6	2.0	4.0	25
Legume	1.0	4.0	7.2	20
Maize silage	1.5	5.4	8.2	67
Rice straw	2.5	2.7	6.2	67
Concentrates				
Formulated concentrate	5.0	5.6	7.4	31
Maize grain	4.0	4.7	5.9	47
Cassava chips	2.8	3.2	4.0	160
Rice bran Gr A	4.5	5.0	7.1	36
Cottonseed meal	5.2	5.8	7.7	13

This farmer has seven mature cows, weighing on average 550 kg, at different stages of lactation, and with daily milk yields ranging from 0 to 20 L/cow. Their energy requirements are presented in Table 17.3, calculated from the Tables in Chapter 6 and Work sheet 1 in Chapter 12.

Cow 7, although not lactating, was in poor body condition prior to drying off. Consequently, she must be fed to gain 1 kg/d of live weight during the last month of pregnancy. The TDN requirements for late pregnancy and such high growth rates are greater than for Cows 4, 5 and 6, all still producing milk. Therefore, even though cows may not be lactating, their daily energy requirements can still be quite high.

Table 17.3 Energy requirements of the small holder's milking cows (in kg TDN/day) at different stages of lactation and pregnancy status

Cow details	Cow 1	Cow 2	Cow 3	Cow 4	Cow 5	Cow 6	Cow 7
Description							
Live weight (kg)	550	550	550	550	500	500	500
Month of pregnancy	0	0	0	3rd	6th	7th	9th
Milk prod (L/d)	20	17	13	10	8	5	0
Fat test (%)	3.6	3.6	3.6	3.6	4.0	4.0	0
Protein test (%)	3.2	3.2	3.2	3.2	3.8	3.8	0
LW gain / loss (kg/d)	–0.5	0	0	0	0	+0.5	+1.0
Energy requirements (kg TDN/d)							
Maintenance	4.1	4.1	4.1	4.1	3.8	3.8	3.8
Activity	0	0	0	0	0	0	0
Pregnancy	0	0	0	0	0.6	0.7	1.4
Milk production	*20 × 0.4* = 8.0	*17 × 0.4* = 6.8	*13 × 0.4* = 5.2	*10 × 0.4* = 4.0	*13 × 0.4* = 5.2	*5 × 0.4* = 2.0	0
Weight gain or loss	*–0.5 × 2.0* = –1.0	*0*	*0*	*0*	*0*	*0.5 × 3.1* = +1.5	*1.0 × 3.9* = +3.9
Total energy requirements	11.1	10.9	9.3	8.1	*7.6*	8.0	9.1

17.3.2 Case study 1: Formulating least cost rations

This farmer wants to formulate a ration for Cow 1 (in Table 17.3) requiring 11.1 kg/d of Total Digestible Nutrients using the cheapest possible ingredients. The cow is in early lactation, non-pregnant and producing 20 L/d of milk, which at 12 Bt/L generates a milk income of 240 Bt/d. The basal forage is immature grass and the main supplement is formulated concentrate. Rather than feed it at the usual rate of 1 kg to 2 L milk, the farmer only wants to feed a total of 7.5 kg/d of concentrates. This case study involves using this range of feeds to formulate the cheapest ration for Cow 1. Four feeding strategies are presented in Table 17.4 as follows:

1 Feeding 50 kg/d of immature grass plus 5 kg/d of formulated concentrate
2 Substituting some of this grass with high-protein legume
3 Substituting some of the concentrate with high-protein cottonseed meal
4 Substituting some of the concentrate with high-energy cassava chips

Table 17.4 Case study 1: Four feeding strategies for Cow 1 (in Table 17.3) producing 20 L/d of milk in early lactation

dry matter (DM); Crude Protein (CP); Neutral Detergent Fibre (NDF); Total Digestible Nutrients (TND).

	Feeding strategy			
	1	2	3	4
Fresh feed intakes (kg/d)				
Immature grass	50	40	50	50
Legume	–	10	–	–
Formulated concentrate	7.5	7.5	5.5	5.5
Cottonseed meal	–	–	2	–
Cassava chips	–	–	–	2
Ration descriptors				
Total DM intake (kg/d)	16.7	17.2	16.8	16.8
Total TDN intake (kg/d)	11.0	11.2	11.4	11.5
CP (%)	13.2	13.3	16.7	12.1
NDF (%)	43	45	44	42
Intake limit (kg DM/d)	15.5	14.8	15.1	15.7
Total feed costs (Bt/d)	77	80	78	73
Milk income less feed cost (Bt/d)	163	160	162	167

Without a computer and a specific ration formulation program, it is very difficult to calculate a ration to provide the exact nutrient requirements, so compromises must be made.

In this case, the rations supply 11 to 11.5 kg/d of Total Digestible Nutrients, NDF% is always too high, hence the appetite limits too low. According to Table 12.1, to allow Cow 1 to fully consume 16.5 kg DM/d, the NDF% should be only 40%, which is just not possible with tropical feeds. Furthermore, cows in early lactation require 16% to 18% CP. This may be the case for intensively fed cows producing 25 or 30 L/d of milk, but for small holder cows, lower protein levels would suffice. Therefore, 13% to 14% CP should be adequate.

The cheapest ration (73 Bt/d) is No. 4, containing grass plus formulated concentrates supplemented with additional cassava chips. The cheapest ration, to produce the same level of milk (valued at 12 Bt/L), means it also has the highest milk income less feed costs.

17.3.3 Case study 2: Feeding cows in early lactation

It costs more money to feed higher yielding cows, but in the long run, it is more profitable. Table 17.5 presents rations formulated to satisfy the energy requirements of Cows 2, 3 and 4 (from Table 17.3) when fed a basal ration of 50 kg immature pasture.

Table 17.5 Case study 2: Profits from feeding Cows 2, 3 and 4 (in Table 17.3) producing 17, 13 and 10 L/d milk
dry matter (DM); Crude Protein (CP); Neutral Detergent Fibre (NDF); Total Digestible Nutrients (TND).

	Cow		
	2	**3**	**4**
Fresh feed intakes (kg/d)			
Immature grass	50	50	50
Formulated concentrate	7.2	4.9	3.1
Ration descriptors			
Total DM intake (kg/d)	16.5	14.4	12.8
Total TDN intake (kg/d)	10.9	9.3	8.1
Milk yield (L/d)	17	13	10
CP (%)	13.1	12.4	11.8
NDF (%)	43	46	48
Intake limit (kg DM/d)	15.3	14.4	13.7
Total feed costs (Bt/d)	76	65	56
Milk income less feed cost (Bt/d)	128	91	64

The 'bottom line' of Table 17.5, the 'milk income less feed costs', clearly indicates that better fed cows produce more milk, and despite their higher feed costs, generate more income. Compared to the highest yielding Cow 2, Cows 3 and 4 only generate 71% and 50% of the milk income over feed costs.

17.3.4 Case study 3: Feeding cows during the dry season

The supply of forages during the dry season is generally the major limiting factor to farm expansion. Rice straw has always been a regular forage source throughout South-East Asia, but for milking cows, it is a very low quality one. Maize silage, however, is an excellent forage, but from Table 17.2, is a more expensive energy source than rice straw (8.2 v 6.2 Bt/kg TDN). The relative energy costs of these two feeds is one way of deciding which one to feed but it should not be used in isolation with other important principles of feeding milking cows to efficiently produce milk. It is unlikely that cows fed rice straw will produce much milk, because their appetites would be limited from the very high amounts of Neutral Detergent Fibre (NDF) consumed. Table 17.6 presents three example rations (X, Y, Z) based on these forages, two with a small amount of mature grass, for Cows 5 and 6 which from Table 17.3, have similar daily total digestible nutrients requirements.

These are just examples of various ways to feed cows when fresh quality forages are in short supply. In this case study, there are large differences in NDF% of these three rations, such that the intake limits are severe on the rice straw-based Ration X compared to the high maize silage Ration Z (9.8 v 12.5 kg DM/d). The difference between the formulated dry matter intake and that calculated from NDF% is presented in Table 17.6 as the value

'A – B', which is considerably higher on Ration X. Therefore, Cows 5 and 6 would be unlikely to be able to consume all of Ration X, causing a decrease in milk yields (from 8 and 5 L/d, respectively) hence a lower 'Milk income less feed cost' compared to Ration Z.

Table 17.6 Case study 3: Three dry season feeding strategies for Cows 5 and 6 (in Table 17.3)
dry matter (DM); Crude Protein (CP); Neutral Detergent Fibre (NDF); Total Digestible Nutrients (TND).

	Ration		
	X	**Y**	**Z**
Fresh feed intakes (kg/d)			
Mature grass	20	20	–
Rice straw	5	–	–
Maize silage	–	20	40
Formulated concentrate	2	1	–
Cottonseed meal	2	1	2
Ration descriptors			
A Total DM intake (kg/d)	14.1	13.4	13.0
Total TDN intake (kg/d)	7.7	8.0	8.6
CP (%)	12.7	11.1	13.2
NDF (%)	61.4	56.3	48.0
B Intake limit (kg DM/d)	9.8	10.7	12.5
A – B (kg DM/d)	4.3	2.7	0.5
Total feed costs (Bt/d)	45	52	70

17.4 Determining the optimum herd size

It is always energetically more efficient to feed fewer cows better. The same total farm volume of milk can be produced with fewer cows. Table 17.7 presents annual energy audits for three herds each producing 50,000 L/yr of milk, with varying numbers of milking cows. Herd A has 10 cows each producing on average 17 L/d, Herd B has 13 cows each producing 13 L/d while Herd C has 17 cows each producing 10 L/d. Daily energy requirements are the same as those for Cows 2, 3 and 4 in Table 17.5, although Table 17.7 expresses them in terms of MJ/d of metabolisable energy (ME) instead of kg TDN/d. The cows produce milk for 300 days and are dry for 65 days. Each herd has a 30% heifer replacement rate, meaning that the farmer must rear 3, 4 or 5 heifers each year. Total energy requirements to rear one heifer for one year are assumed to be 22,000 MJ of ME.

Cows in the higher yielding Herd A use less of their daily energy intakes for maintenance (40 v 46 v 52%), allowing them to be more efficient on a day-to-day basis. Compared to Herds B and C, milking cows in Herd A then require 12% and 29% respectively less of their daily energy intakes to produce the same total volume of milk.

After taking into account all the farm dietary energy costs associated with producing milk (including maintaining dry cows and rearing heifers), Table 17.7 expressed this as the total energy requirements to produce the same volume of milk (in MJ/L milk). This amounted to 11.0 for Herd A compared to12.8 for Herd B and 15.0 MJ/L for Herd C.

Table 17.7 also presents the 'Productive feed energy' or the percentage of total farm energy used by milking cows when lactating. Again Herd A is the most efficient with 81%

of its annual feed energy used to produce milk in the lactating cows, compared to 78% (Herd B) and 76% (Herd C).

Table 17.7 Annual energy audit for three herds producing 50,000 L/yr of milk

	Herd		
	A	B	C
Milking cows	10	13	17
Total milk yield (L/cow/yr)	5000	3846	2941
Average milk yield (L/cow/d)	16.7	12.8	9.8
Daily energy requirements (MJ/d)	148	128	113
Energy for maintenance (%)	40	46	52
A Total farm energy for milk prod (000 MJ/300 d)	444	499	576
Daily energy cost to produce milk (MJ/L)	8.9	10.0	11.5
B Total farm energy for dry period (000 MJ/65 d)	39	51	66
C Rearing heifer replacements (000 MJ/yr)	66	88	110
Total farm requirements or *A* + *B* + *C* (000 MJ/yr)	549	638	752
Productive feed energy (%) = *A* / (*A* + *B* + *C*)	81	78	76
Total energy cost to produce milk (MJ/L)	11.0	12.8	15.0

Table 17.7 clearly shows the energetic efficiency of feeding fewer higher yielding cows. However, as well as considering the costs of sourcing that energy, other factors must be taken into account when determining herd profitability, and these will be discussed in the following section.

17.5 Other factors influencing herd profitability

'Milk income less feed costs' is based on the daily feed intake of milking cows and, because Herd A (in Table 17.7) is energetically the most efficient, this would also be expected to be higher than for the other two herds, as they are for Cow 2 is Table 17.5. However, this conclusion is based on the assumption that the milk responses to supplements do not differ between herds (see Chapter 11). Consequently the profitability of feeding supplements in Herd A, compared to those in Herds B and C, may be reduced as Herd A cows would have been fed better to produce more milk.

Another factor influencing herd profitability is the marginal cost, or the cost of each additional unit of energy that is fed. For example, higher quality forages and concentrates often cost more and better fed cows may require

It is very important to monitor the weight of fresh forage offered to each animal (East Java, Indonesia).

these higher quality feeds. To maintain their higher levels of milk production, Herd A cows would require rations providing extra protein and less fibre. Higher yielding cows have greater demands for protein even if their marginal energy requirements are the same per litre of milk produced. Furthermore, such animals must maintain higher feed intakes, which would be more adversely affected by high fibre diets. The cost of providing such rations for high yielding cows may be higher than for lower yielding cows. As this would increase feed costs, profitability levels are likely to decline.

Milk composition depends on nutrient intake (see Chapter 14) and Herd A cows would be fed a better balanced ration supplying more energy and protein and less fibre each day than Herd B and C. It is then likely that milk composition may vary between herds. Herd A cows would produce milk with more milk protein, because of their better energy status, and more milk fat, unless their ration becomes deficient in dietary fibre, which is unlikely because all tropical forages have such high fibre levels. In many countries in South-East Asia, higher milk solids contents return a higher unit milk price, thus providing financial benefits to better fed herds.

Unit milk price can also be affected by milk quality, or the level of bacterial contamination. This is greatly influenced by on-farm hygiene. In South-East Asia, milk quality payments are given on both objective and subjective assessments. For example in Thailand, the objective assessments are actual measures of bacterial contamination, while the subjective assessments are based on inspection of farm equipment and facilities. For cows in Herd A to produce 5000 L milk/lactation, their overall farm management must be excellent. Not only does this include feeding, but also the health, milking, reproduction and rearing of young stock. It is then likely that any subjective assessment for milk quality would be provide maximum premiums, hence increase unit milk price, hence 'milk income less feed costs'.

The data in Table 17.7 were calculated on the assumption that cows produced one calf each year and 30% of the heifers were used as herd replacements. From Chapter 15, cows provided with adequate energy have higher fertility because they are more likely to cycle earlier post-calving. It is likely that Herd A cows will cycle earlier than Herd B or C cows because of their higher feed, hence energy intakes. Consequently, heifer replacement rates may differ as a result of different culling pressures in the three herds.

If 'milk income less feed costs' were calculated on a whole-farm basis over 12 months, Herd A would be the most profitable. Its higher energetic efficiency and greater unit milk price would offset any greater substitution rate and higher unit feed costs discussed above. The above factors highlight the complex interactions between feeding management, milk responses and herd profitability. Ideally all biological responses should be expressed in terms of financial returns less cost inputs. At least in nutrition, there are now the tools to do this with more confidence than in other areas of farm management.

17.6 Improving unit returns for milk

Sanderson (2004) argues rightly that there is no point in focusing on nutrition, breeding and other improved herd management if the infrastructure of the industry is not in place to ensure that the raw milk is supplied to the milk processor in a clean and safe manner. Too often, particularly in warm climates, breakdowns in milking hygiene have led to serious outbreaks of food poisoning. Even for dried milk products such as powder, the processing costs can be dramatically increased and the longevity of the end product can be markedly reduced, in raw product with high levels of bacterial contamination. Even though milking hygiene is not an integral part of feeding management, its influence on unit milk returns justifies its brief mention in this manual.

17.6.1 Milk composition

As already mentioned, improving milk composition, or the content of milk fat, protein or Solids-Not-Fat (SNF), can increase unit milk returns. Chapter 14 discusses the effects of feeding management on milk composition. Each country in South-East Asia has developed its own unique milk pricing structure, which incorporates premiums and penalties based on milk composition. Countries with more developed milk analytical laboratories can test for milk fat and solids-not-fat ,while others only use Total Solids (TS) in their pricing structure (see Tables 17.8 and 17.9 for examples of such payment schedules).

17.6.2 Milk quality

Milk quality refers to the level of various contaminants in milk, be they bacterial, chemical or any other adulterations that can be detected. In many South-East Asian countries, however, the term 'milk quality' covers milk composition, hygiene and adulteration.

Adulteration of milk can be intentional or unintentional. Intentional adulteration occurs when farmers add compounds to the raw milk (eg water and sugar) in an attempt to increase its volume and at the same time, maintain its density, so the hygrometer will not detect changes in specific gravity. If successful, such farmers will receive a higher payment for volume with a similar payment for estimated total solids content. Organoleptic (or taste) and alcohol tests can normally detect such adulterations with the resultant penalty, or even outright rejection. Antibiotics can also be classified as intentional adulteration, occurring when farmers do not follow the recommended drug withholding periods following animal treatments. Tests for antibiotics and inhibitory substances are now routine in most South-East Asian countries.

Unintentional contaminations can occur either from within the milking cow, such as mastitis, or more usually following milk harvesting. The somatic cell count detects mastitis while an initial screening can be done using the Californian (or Rapid) Mastitis Test.

Inferior milking hygiene is the major cause of poor milk quality and can arise:

Poor milking hygiene will reduce the unit return for milk (Central Java, Indonesia).

- on-farm, through poor cleaning and sterilising practices of milk harvesting equipment
- post-farm gate, due to unclean milk handling and storage equipment and delays to cooling.

Constructing fireplaces in the cowshed ensures good hot water supplies for on farm milking hygiene.

Installing gas fired hot water units in Milk Collection Centres ensures good milking hygiene post farm gate.

The key to any successful domestic milk production system is the establishment of a satisfactory milk harvesting, storage and transport infrastructure. Milk must be harvested in a clean and hygienic manner and cooled as quickly as possible, if it is to have any value for processing. There are several measures of milk contamination following harvest, transport and storage such as Total Plate Count (TPC), Methylene Blue Reductase Test and Resazurin Test. Total plate count is measured in millions of colony forming units per millilitre of milk (M/mL). These tests and the key principles of good milking hygiene practices are fully described in the final report on our Indonesian and Malaysian milking hygiene workshops (Moran *et al.* 2004).

To give examples of the magnitude of measures of milk composition and quality on unit returns of milk from small holder dairy farmers, the current payment schedules for raw milk in Malaysia and Indonesia are presented in Tables 17.8 and 17.9. Small holder dairy industries are very different in these countries in that the infrastructure to handle raw milk post-farm gate is very poor in Indonesia, leading to considerable bacterial contamination once milk leaves the farm.

The Malaysian government penalises farmers for low TS% and SNF%, the latter being determined using fat tests, and high total plate count, with levels over 1 M/mL being severely penalised. The particular milk processor in Indonesia only uses TS% as a measure of milk quality whereas, because of the problems with maintaining milk temperature during transport, it includes an incentive payment for extra cool milk.

Milk produced in Indonesia suffers from low TS% and very high TPC levels. The base payment is given to milk with 11.3% TS, 20 to 30 M/mL TPC and 6 ^{o}C to 8 ^{o}C, compared to 11.75% TS and less than 0.25 M/mL TPC in Malaysia. Note the marked difference in acceptable TPC levels in raw milk from these two countries.

One session in our milking hygiene workshops is called 'Milk quality makes money' (Moran *et al.* 2004), because of the large financial benefits arising from improved milking hygiene practices. For Malaysian farmers, improving milk grade from D to A (see Table 17.8) through reducing TPC levels from 0.5 to 0.25 M/mL will increase unit milk price by 12%. For farmers with poorer milk harvesting practices, improving milk grade from G to D, through reducing TPC levels from less than 1 M to less than 0.5 M/mL will increase unit milk price by 29%.Clearly this is an enormous price signal to improve milking hygiene with smallholder farms quickly responding.

Table 17.8 Milk quality payments used by the Malaysian government in 2005
solids-not-fat (SNF); total solids (TS); Total Plate Count (TPC); Malaysian Ringgit (MR). Base price is 1.23 MR/L for milk containing 3.25% fat, 8.5% SNF and 11.75% TS. (Source: Moran *et al.* 2004)

Grade	Milk composition			Milk quality		Final price
	SNF(%)	TS(%)	Incentive (MR/L)	TPC (M/mL)	Penalty (MR/L)	(MR/L)
A	>9.25	>12.5	0.12	<0.25	0	1.35
B	9.0–9.25	12.25–12.5	0.06			1.29
C	8.5–9.0	11.75–12.25	0			1.23
D	>9.25	>12.5	0.12	0.25–0.5	–0.15	1.20
E	9.0–9.25	12.25–12.5	0.06			1.14
F	8.5–9.0	11.75–12.25	0			1.08
G	>8.5	>11.75	0	0.5–1.0	–0.30	0.93
X				>1.0		0.50

Table 17.9 Milk quality payments used by an Indonesian milk processor in West Java in 2005
total solids (TS); Total Plate Count (TPC); temperature (temp); Rupiah (Rp); Base price is 1720 Rp/L (Source: Moran *et al.* 2004)

Milk composition		Milk quality			
TS(%)	Bonus (Rp/L)	TPC (M/mL)	Bonus (Rp/L)	Temp. (°C)	Bonus (Rp/L)
<10.7	–25	<1	100	>8	–10
10.7–10.9	–20	1–3	75	**6–8**	**0**
11.0	–15	3–5	50	<6	10
11.1	–10	5–10	40		
11.2	–5	10–15	20		
11.3	**0**	15–20	10		
11.4–11.6	20	**20–30**	**0**		
11.7–11.9	30	30–40	–10		
>12.0	40	>40	–20		

Financial benefits are less clear in Indonesia because milk quality is not monitored for individual farmers, just for the dairy cooperative they supply. If such a cooperative handling 30 t/d of raw milk can reduce TPC levels from 30 M/mL to 5 M/mL, it would generate an additional 3% from milk sales, or 45 M Rp/mth. Reducing TPC levels from 30 M/mL down to 1 M/mL would generate an additional 6%, or 90 M Rp/mth. As well as returning some of these premiums to individual farmers, there are many opportunities to invest in better milk handling equipment and practices, such as those suggested by workshop participants and reported by Moran and Miller (2004). Surprisingly such clear price signals have not had much impact on milking hygiene practices in Indonesia.

17.7 Economic analyses of small holder dairy systems

17.7.1 Results from a survey in Thailand

Skunmun and Chantalakhana (2000) undertook whole farm economic analyses of 10 small holder farms in Thailand, with dairy stock numbers per farm varying from 6 to 30 milking cows, 3 to 26 growing heifers and 1 to 6 female calves. Cow milk yields ranged from 6 to 12 L/d. They found that the average cost of milk production for the entire herd, which included cash and non-cash (eg land rent, labour, depreciation) costs, was 10.5 Bt/L, with milk returning only 8.5 Bt/L, considerably lower than the 12 Bt/L received by farmers in 2005. They then concluded that, after taking into account all the costs involved, small holder dairy farming was not a profitable enterprise with that level of milk returns.

The feed costs were broken down into those for roughages and concentrates. As a proportion of whole farm costs, roughage costs were 23% (ranging from 16 to 32%), concentrate costs were 34% (ranging from 20 to 46%) and total feed costs were 58% (ranging from 51 to 67%).

Skunmun and Chantalakhana (2000) were able to break down the total farm costs of producing milk into those associated with growing out young stock and maintaining dry cows. Of the 10.5 Bt/L total cost, 34% was attributed to growing out replacement heifers, 12% to maintaining cows when dry and 54% to maintaining cows while milking. This clearly shows that managing non-productive stock is a major expense for small holder farmers.

17.7.2 Comparing farming systems in Vietnam

In many countries, small holder dairying began in peri-urban areas, but because of increasing population pressures leading to higher feed costs, it has progressively became rural-based. Cai *et al.* (2000) compared the profitability of small holder dairying in rural (Binh Duong province) and peri-urban (Ho Chi Minh City) areas of South Vietnam. They used the following assumptions:

- cows were milked for 300 days, produced 3900 L, followed by a 120-d dry period
- cows were culled after four lactation cycles
- one of the four calves was reared as a replacement, giving a replacement rate of 25%.

The assumed costs and returns are presented in Table 17.10 where the major difference between the two systems was the supply of forages, either home grown or purchased, and the costs of some of the purchased feeds. Each cow on rural farms consumed 25 kg/d of on-farm and 5 kg/d of purchased forages whereas each cow on peri-urban farms consumed 5 kg/d of on-farm and 25 kg/d of purchased forages. Other feeds consumed (in kg fresh feed/cow per day) were formulated concentrates (3.5 while milking and 1.0 kg fresh feed/cow per day while dry), rice straw (2.0 kg fresh feed/cow per day), brewers grain (2.0 kg fresh feed/cow per day), cassava residue (2.0 kg fresh feed/cow per day) and soybean curd (2.0 kg fresh feed/cow per day). Heifer rearing costs were also lower on rural farms because of the greater supply of on-farm forages.

Two tables present farm profitability data for new farmers purchasing their cows (Table 17.11) or for established farmers using their own heifer replacement (Table 17.12). Unlike the Thai study above (Skunmun and Chantalakhana 2000), dairying was profitable on both rural and peri-urban farms. For new farmers, feed costs comprised 50 to 60% of total production costs. Profit margins were more than four times higher on rural farms because of their lower total feed costs, which were only 66% of those on urban farms.

Table 17.10 Cost and returns on rural and peri-urban farms in South Vietnam

Amounts are shown in in Vietnam Dong (VND). Those feed costs that differ between rural and peri-urban farms are shown in italics. (Source: Cai *et al.* 2000)

	Rural farms
Feed costs (VND/kg fresh)	
On-farm forage	100
Purchased forage	200 (*300 peri-urban*)
Formulated concentrates – milking	2100 (*2300 peri-urban*)
Formulated concentrates – dry cow	1900 (*2300 peri-urban*)
Rice straw	200 (*550 peri-urban*)
Brewer's grain	500 (*400 peri-urban*)
Cassava residue	200
Soybean curd	400
Other costs (VND)	
Daily milk transport	2500
Total AI costs/conception (2.5/conception)	375,000
Veterinary cost/lactation cycle	300,000
Shed maintenance/cycle	125,000
Shed construction over 10 years	2,500,000
Other equipment or investments/cycle	1,200,000
Cow purchase	11,500,000
Rearing heifer from birth to first calving (per milking cow)	467,000 (*756,000 peri-urban*)
Interest on loans (% per year)	12
Returns (VND)	
Milk sales/litre	3200
Cull cow sale	3,500,000
Bull calf value	200,000
Heifer calf value	1,000,000
Monthly manure sales	25,000

The reduced costs through rearing their own replacements increased profitability, particularly for peri-urban farmers (Table 17.12). Using milk income less feed costs, rural farmers were 46% more profitable than the peri-urban farmers, whereas profit margins (taking into account all farm costs) were 96% higher for the rural farmers.

Another useful measure is the total cost of production, expressed as VND/L milk. From Tables 17.11 and 17.12, this ranged from a low of 1,945 VND/L for the established rural farmer to a high of 3,240 VND/L for the new urban farmers. For fresh local milk to remain competitive with reconstituted milk from imported ingredients, Sanderson

(2004) considered that farmers should expect to receive no more than US 20 to 30 c/L, or 3,170 to 4,740 VND/L at current exchange rates (see Appendix 3).

Table 17.11 Profitability of small holder dairying on rural and peri-urban farms in South Vietnam, for new farmers purchasing their cows

* Operational costs calculated as 5% of feed costs. (Source: Cai *et al.* 2000)

Farm type	**Rural**		**Peri-urban**	
Cost or return category/420-day lactation cycle	**VND (000)**	**% Total costs**	**VND (000)**	**% Total costs**
Feed costs				
Formulated milking cow concentrates	2,205	22	2,415	19
Other milking cow purchased feeds	780	8	990	8
Formulated dry cow concentrates	252	3	276	2
Other dry cow purchased feeds	48	–	156	1
Roughages	1,470	15	3,360	27
Total feed costs	*4,755*	*48*	*7,197*	*57*
Other operating costs				
AI	375	4	375	3
Veterinary	300	3	300	2
Milk transport	750	7	750	6
Housing	437	4	437	3
Other equipment or investments	300	3	300	2
Operational (electricity, water) *	238	2	360	3
Total other operating costs	*2,400*	*23*	*2,522*	*19*
Cow purchase				
Purchase cost	2,000	20	2,000	16
Loan interest	920	9	920	7
Total costs	*10,075*	*100*	*12,639*	*100*
Total cost/L milk (VND)	*(2,583)*	–	*(3,240)*	–
Returns				
Milk sales	12,480	124	12,480	99
Calf sales/value	600		600	
Manure sales	350		350	
Total returns	*13,430*	*133*	*13,430*	*107*
Total returns/L milk (VND)	*(3,443)*	–	*(3,443)*	–
Profit per cow	3,355		791	
Annual profit	2,915		687	
Profit per litre milk (VND/L)	860		202	
Milk income less feed costs (VND/L)	1,980		1,354	

Even at this lowest milk return (US 20 c/L or 3,170 VND/L), small holder dairy farming can still remain profitable. In addition to milk sales, each litre of milk returns an additional 243 VND from non-milk returns (calf and manure sales), thus grossing 3,413 VND/L, and providing just 173 VND/L profit for the new urban farmer.

In most western studies of profitability of dairy farming, economic analyses of farm profits usually incorporate a component for labour costs (and/or management skills) since farmers can generate other income if they are not dairying. Such analyses are undertaken to assess whether farmers could spend their time more profitably undertaking other forms of income generation. However, in most developing countries, such analyses can provide a guide as to the level of support required for dairying to be economically viable, hence not require government or institutional financial support.

Table 17.12 Profitability of small holder dairying on rural and peri-urban farms in South Vietnam, for established farmers rearing their own replacement heifers
(Source: Cai *et al.* 2000)

Farm type	Rural		Peri-urban	
Cost or return category/420 day lactation cycle	**VND (000)**	**% total costs**	**VND (000)**	**% total costs**
Total feed costs	4,755	62	7,197	69
Total other operating costs	2,400	32	2,522	24
Heifer replacement costs	467	6	756	7
Total costs	*7,622*	*100*	*10,475*	*100*
Total cost/L milk (VND)	*(1,954)*	–	*(2,686)*	–
Total returns	*13,430*	*176*	*13,430*	*128*
Profit per cow	5,808		2,955	
Annual profit	5,047		2,568	
Profit per litre milk (VND/L)	1,489		758	
Milk income less feed costs (VND/L)	1,980		1,354	

17.8 Flow charts of feeding decisions that drive profit

Flow charts of the major feeding management decisions driving profit are presented in Figures 17.1 and 17.2. For each component in Figure 17.1, the feed inputs, the cost of home-grown inputs depend on their quality and availability, both of which are under farmer control. However, the cost of purchased feed inputs are driven by market forces, although farmers can influence these by purchasing these when they are in plentiful

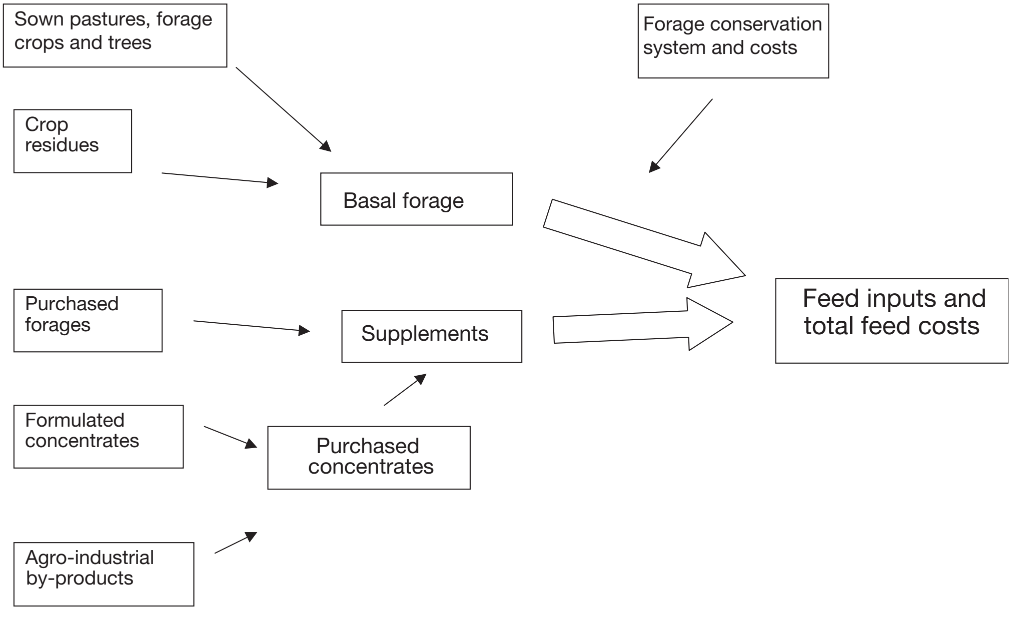


Figure 17.1 Components of feed inputs in small holder dairy farms.

supply, when they are likely to be cheaper.

For fresh forages, such as maize greenchop or grasses, or for wet by-products, such as brewer's grain or soybean curd, total costs must include conservation (as silage) until required. Dry feeds could also be purchased when cheapest but would then require some storage costs. In addition, such purchases may necessitate relatively large cash investments, hence some opportunity cost (such as ongoing interest rates) should be incorporated.

Home-grown forages should also be fully costed, preferably on the basis of cost per unit nutrient, keeping in mind that agronomic decisions to optimise quality, such as using inorganic fertilisers or using a short harvest interval, may increase cost per unit dry matter, but not necessarily per unit of feed nutrient. Furthermore, the cost of supplementing with additional nutrients from other feed sources is included in the final calculation of daily total feed costs per animal. This often leads to the conclusion that an investment in optimising forage quality (which can also improve milk yield) is worthwhile as it reduces supplement costs and/or increases milk return, and thus increases milk income less feed costs.

Figure 17.2 incorporates other factors influencing overall farm profits, such as feeding non-productive dairy stock, disease, fertility and cow genetic merit. Costing such factors is beyond the scope of this manual.

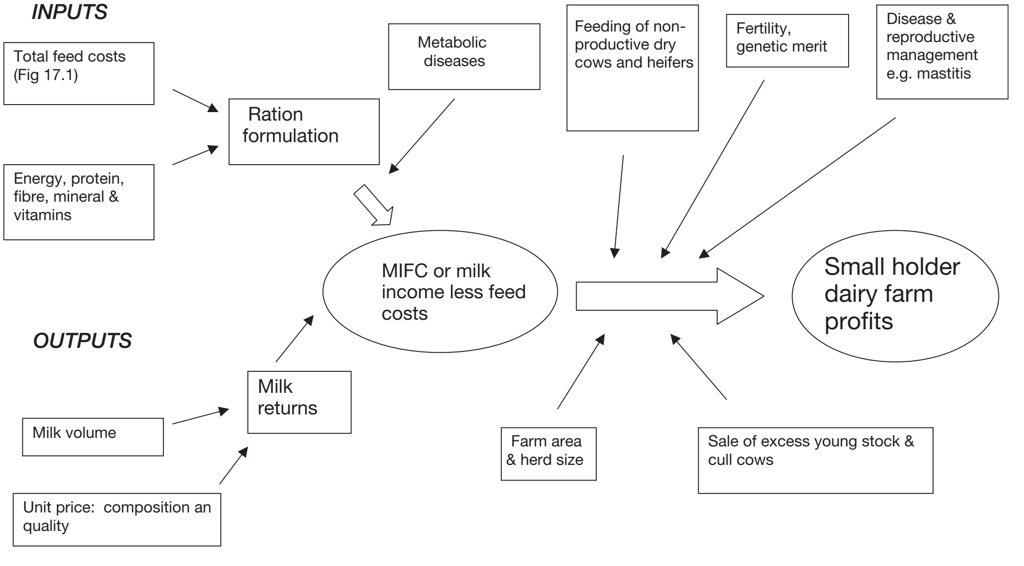


Figure 17.2 Feeding management decisions driving farm profits.

18

Body condition scoring

This chapter:

Explains a new system of scoring the body condition of dairy stock.

The main points in this chapter:

- body condition is the amount of muscle and fat covering the cow, hence the body reserves available to provide additional nutrients for milk production and efficient reproduction
- there are 5 key areas on the body regions of cows that need to be assessed, namely the area between the tail head and pin bones, inside of the pin bones, backbone, hips and depression between the hips and pin bones
- the basis for scoring system is a flow chart, with photographs of cows in varying body condition to provide support
- target body condition scores are presented for different stages of the lactation cycle
- suboptimum body condition scores reduce milk yields and reproductive performance.

Condition scoring is the visual assessment of the amount of muscle and fat covering the bones of the cattle. It can be assessed independently of live weight, gut fill and pregnancy status and involves observing specific points on the animal. Body condition affects milk production and reproductive performance. Scoring enables farmers to compare the condition of their cows with recommended targets. Knowledge of condition scoring then enables farmers to manage their feeding programs better.

This chapter provides a common language for farmers, advisers and researchers to describe the body condition of any breed of dairy cattle. The pictures in this chapter are of Friesian cows, although the descriptors are equally applicable to Jersey (and other dairy) or Zebu cattle.

The system described in this chapter has been used for many years in Victoria and ranges from emaciated/very little flesh over the skeleton (score 1) to very fat/heavy fat cover (score 8). Only cows in scores 3 to 6 are described in this chapter. Cows with scores of 3 or less are very thin and are either severely underfed or are suffering from disease or injury. Cows with scores of 6 and over are over fat and are at risk of suffering from metabolic diseases around calving.

These pictures and diagrams were developed for an extension package, called 'The Condition Magician' by Chrisanya Robins and Richard Stockdale, of Kyabram Dairy Centre, in northern Victoria (Robins *et al.* 2003).

18.1 The system of condition scoring

The score is determined by assessing five key areas of the cow (Figure 18.1):

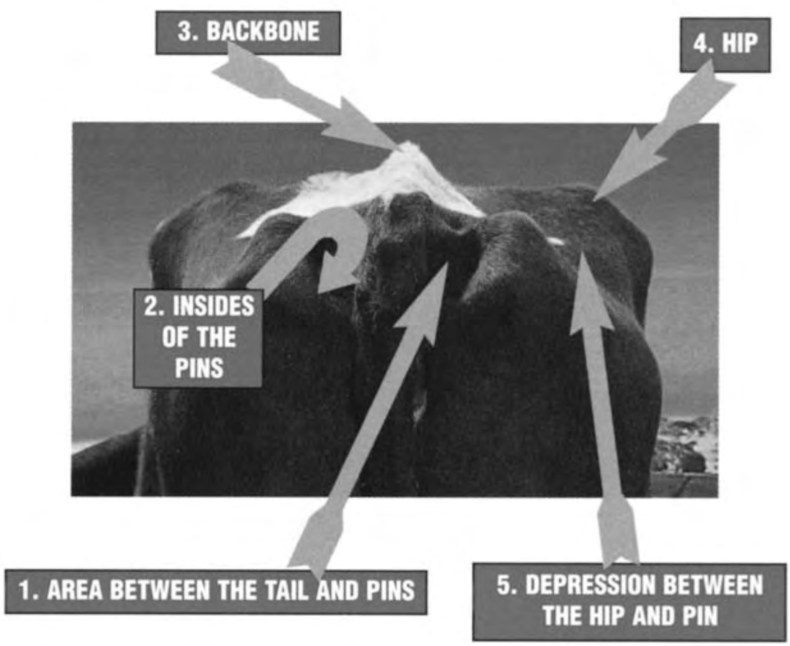


Figure 18.1 The five key areas to assess body condition score.

1 **The area between the tail and the pin bones.** This is the area where it is easiest to see if cows are starting to lay down fat. it can be described as 'deeply sunken', 'sunken', 'slightly sunken' or 'filled in' (see Figure 18.2).
2 **The insides of the pin bones.** From Figure 18.2, this area can be described either as 'hollow' or as 'not hollow'. If the area between the tail and pin bones is deeply sunken and the inside of the pins is hollow, the cow is in score 3. If this area is not hollow, the cow is in score 3.5.
3 **The backbone.** From Figure 18.2, the backbone can be described as a 'bumpy ridge' or 'not a bumpy ridge'. If the area between the tail and pin bones is sunken and the backbone is a bumpy ridge, the cow is in score 4. If the backbone is not a bumpy ridge, the cow is in score 4.5. Research has shown that cows start to lay down subcutaneous fat at score 4.5, and this is evident along the backbone.

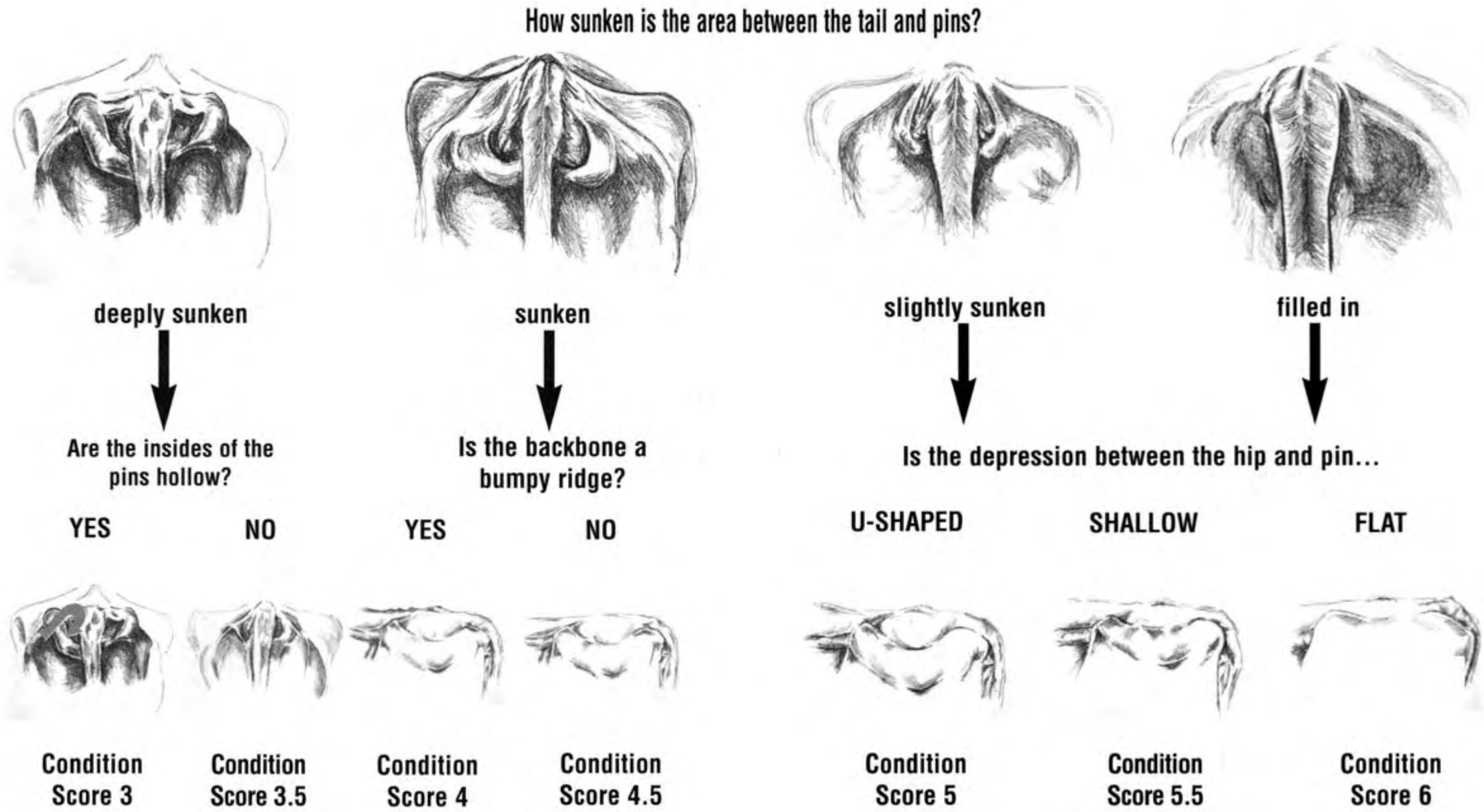


Figure 18.2 A flow chart for quantifying body condition scores using visual assessments of the area between the tail and the pin bones, the inside of the pin bones, the backbone and the depression between the hip and pin bones.

4. **The hips.**
5 **The depression between the hip and pin bones**. From Figure 18.2, the depression between the hips and pin bones can be described as 'U-shaped', 'shallow' or 'flat'. If the area between the tail and pin bones is slightly sunken and the depression between the hip and pin is U-shaped, the cow is in score 5. If the depression is shallow, the cow is in score 5.5. If the area between the tail and pin bones is filled in and the depression is flat, the cow is in score 6.

18.2 Examples of body condition scores

The following four photographs are of cows in various condition scores.

Figure 18.3 Condition score 3. This cow has:
- deeply sunken area between tail and pins
- a hollow area inside the pins
- very prominent hips and backbone
- a backbone that is a very bumpy ridge.

Figure 18.4 Condition score 4. This cow has:
- sunken area between the tail and the pins
- a backbone that is a bumpy ridge
- hips and pins slightly rounded.

Figure 18.5 Condition score 5. This cow has:
- slightly sunken area between the tail and pins
- a U-shaped depression between the hip and pin
- rounded backbone and rounded hips and pins.

Figure 18.6 Condition score 6. This cow has:
- filled in area between the tail and pins
- flat depression between the hip and pin
- a rounded backbone.

18.3 Target body condition scores

For optimal milk production and reproductive performance (Morton *et al*. 2003), it is important to:

- ensure all cows are in body condition score between 4.5 and 5.5 at calving
- ensure cows do not lose excessive body condition during early lactation – losses of more than one condition score in early lactation are considered excessive.

Condition scoring should be done throughout the year to take account of seasonal variations in feeding management, but particularly at the following stages of the lactation cycle:

1. At drying off, when cows that are too thin or too fat should be managed to achieve the target by calving.
2. Just before calving, and if there are still too many thin or fat cows, feeding management should be changed for future calvings.
3. At 40 to 60 days after calving, to assess body condition loss in early lactation. If it is excessive, feeding management should be changed leading to the next calving and in early lactation.

Three separate scoring sheets should be used for cows: at drying off, for cows at calving and for cows scored 40 to 60 days after calving. The date, cow identity number and condition score should be recorded for each cow. On a regular basis, the proportion of cows that are outside the target condition scores (4.5–5.5) should be determined. For each cow, the condition score at calving is subtracted from the condition score 40 to 60 days after calving. The average value for the entire herd should be calculated to compare with the target (less than one condition score).

18.3.1 Interpreting body condition scores at calving

Table 18.1 should be used to decide on future feeding management.

Table 18.1 Body condition scores at calving, risk of losses in milk production and reproductive performance, and future changes in feeding management
(Source: Morton *et al.* 2003)

Proportion of cows	Interpretation	Risk	Future feeding management
Below 4.5 score			
Less than 5% (or 1 cow in 20)	Few cows are too thin	Low	No change required
5–15% (or 1–3 cows in 20)	Likely to be too many thin cows	Moderate	Consider improving feeding management
More than 15% (or 3 cows in 20)	Too many thin cows	High	Should improve feeding management
Above 5.5 score			
Less than 5% (or 1 cow in 20)	Few cows are too fat	Low	No change required
5–15% (or 1–3 cows in 20)	Likely to be too many fat cows	Moderate	Consider modifying feeding management
More than 15% (or 3 cows in 20)	Too many fat cows	High	Should modify feeding management

If more than 15% of the milking cows have condition scores below 4.5 or above 5.5 at calving, action is required. For herds with too many thin cows, this can take the form of increasing feeding levels during late lactation and/or the dry period of these thin cows or even considering drying them off early. If most of them are calving for the first time, then heifer management should be reviewed (see Chapter 16).

For herds with too many fat cows, action can take the form of reducing feeding levels of these fat cows during the dry period. If most of them are those with a poor history of fertility and with long dry periods, greater attention should be given to improving their reproductive performance (see Chapter 15).

Incorrect diet balance, such as low protein levels, may be a cause. Other dietary imbalances are discussed in Chapter 13.

18.3.2 Interpreting changes in body condition during early lactation

Table 18.2 should be used to decide on future feeding management.

If, during early lactation, more than 15% of the cows have lost more than one condition score or if the average condition score loss was more than 0.6 units, post-calving feeding management should be addressed. As well as increasing feed offered, this can take the form of reducing moisture levels in fresh forages through wilting, or improving forage quality through feeding less mature forages. The quality and amount of concentrates on offer should also be reviewed.

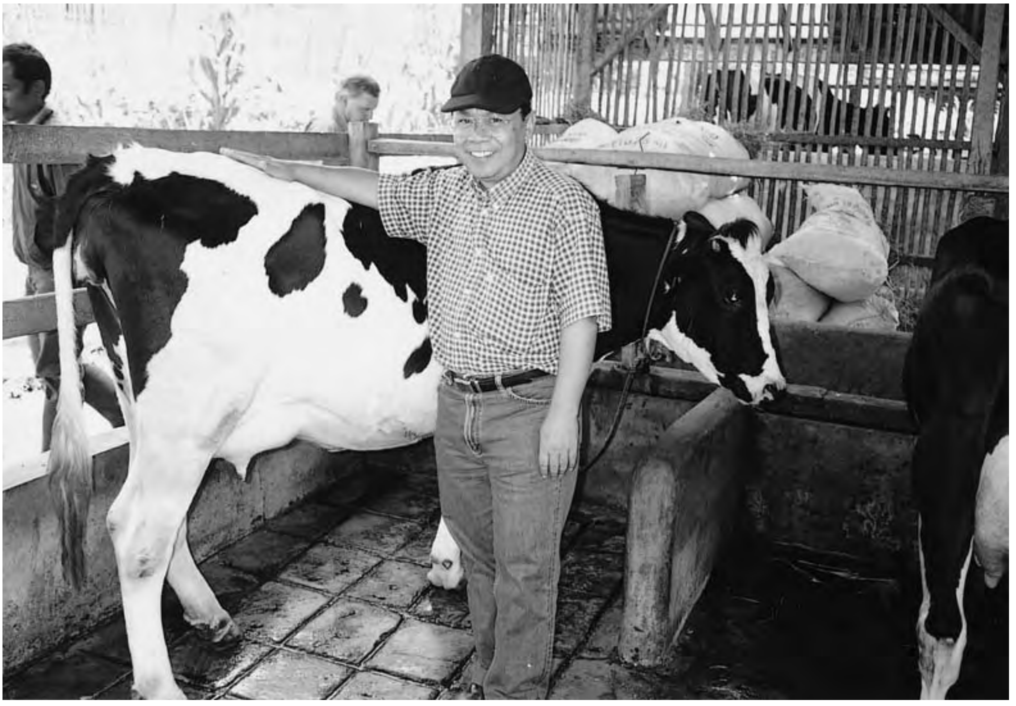
Table 18.2 Average value for body condition changes in early lactation, risk of losses in reproductive performance and future changes in feeding management
(Source: Morton *et al.* 2003)

Average value	Interpretation	Risk	Future actions
Less than 0.45	Few cows have lost excessive condition	Low	Check condition at calving. If too low, improve feeding management
0.45 to 0.6	Likely to be cows losing excessive body condition	Moderate	No action required
More than 0.6	Too many cows losing excessive body condition	High	Improve feeding management

18.4 Effect of suboptimal body condition on cow performance

Australian dairy researchers and advisers have developed an extension program to address poor reproductive performance, called 'InCalf' (Morton *et al.* 2003). This program identified six key factors affecting herd reproduction, of which one was body condition (see Chapter 15). The program then quantified the benefits of improving body condition scores towards the targets described above (InCalf 2004a, 2004b). Benefits arise from improved reproductive performance and milk production.

A thin, low yielding Local Indian Dairy cow in northern Malaysia.



An imported Fresian heifer from North America. Such animals must be very well managed to ensure good fertility as well as milk yields (West Java, Indonesia).

18.4.1 Effects on reproductive performance

Condition score at calving

Cows with less than 4.5 condition score at calving have 100-day in-calf rates at least 12% percentage units lower than if they calved within the optimal range of 4.5 to 5.5. Furthermore, cows that lose more than one condition score between calving and mating have reduced reproductive performance compared to cows with more moderate losses. Excessive condition score losses are more likely in cows calving above score 5.5.

The adverse effect of body condition scores below 4.5 or above 5.5 on 100-day in-calf rate are presented in Table 18.3. This table can be used for a test herd as follows:

1 The test herd's current condition score profile is determined.
2 The particular cell in the table is identified for the percentage of cows in the test herd with <4.5 and >5.5 condition scores. This cell is the expected percentage decrease in 100-day in-calf rate compared to a herd where all cows are between 4.5 to 5.5 condition score at calving.
3 Following improvements in feeding management, the herd's new (ie expected) condition score profile is estimated.
4 That particular cell in the table is identified.
5 The difference between the two figures gives the improvement as a result of the change in feeding management.

Table 18.3 Possible changes in 100-day in-calf rate percentage units with varying percentages of cows in condition scores less than 4.5 or more than 5.5 at calving
Numbers in bold italics are those from an example in the text. (Source: InCalf 2004a).

% Cows with <4.5	% Cows with >5.5:										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	0	0	–1	–1	–2	–2	–2	–3	–3	–4	–4
10	–1	–2	–2	–2	–3	–3	–4	–4	–4	–5	
20	–2	***–3***	–3	–5	–5	–4	–5	–5	–5		
30	–3	–4	–4	–6	–6	–5	–6	–6			
40	–4	–5	–5	–7	–7	–6	–7				
50	–6	–6	–6	–8	–8	–8					
60	–7	–7	***–7***	–9	–8						
70	–8	–8	–9	–9							
80	–9	–9	–10								
90	–10	–10									
100	–11										

For example, when first monitored, the test herd of 10 cows has six cows with a score below 4.5, two cows between scores 4.5 and 5.5 and two cows above score 5.5 at calving (ie 6:2:2; score –7, Table 18.3). Following improved feeding management during late lactation and/or the dry period, the condition score profile of the herd changes to two cows below score 4.5, 7 cows between score 4.5 and 5.5 and one cow above score 5.5 at calving (ie 2:7:1; score –3, Table 18.3). This is close to the In Calf recommendation of <15% of cows below 4.5 and <15% above 5.5. Changes in the 100-day in-calf rate for this herd are from –7 to –3 (from Table 18.3), an improvement of 4% units.

The InCalf (2004a) program determined a financial benefit from improved condition score at calving on fertility, of A$310 per 100 cows per 1% increase in the 100-day in-calf rate. This is based on the assumption that condition score at calving has no effect on reproductive performance after the first three cycles (the first 63 days) of the mating period, that is up to Day 113 in a herd with a voluntary waiting period of 50 days. For dairy industries in countries outside Australia, such economic benefits still need to be determined.

Condition loss in early lactation

The average condition score loss prior to mating can provide a guide to the effect of the proportion of cows with excessive body condition loss (more than 1.0 condition score) on herd fertility (100-day in-calf rate) and infertility (200-day not-in-calf rate) (Table 18.4).

Table 18.4 Average value for body condition changes in early lactation, likely percentage of cows losing more than 1.0 score, and possible decrease in 100-day in-calf and increase in 200-day not-in-calf rates
(Source: InCalf 2004b)

Average condition score loss in early lactation	Percentage cows losing >1 condition score	Percentage decrease in 100-day in-calf rate	Percentage increase in 200-day not-in-calf rate
Less than 0.45	–	–	–
0.45–0.6	–1	–1	0
0.6–0.75	–2	–2	1
0.75–1.0	–4	–4	2
More than 1.0	–5	–5	3

The InCalf (2004b) program also determined a financial benefit from improved fertility as a result of reducing body condition losses prior to mating, namely A$590 per 100 cows per 1% increase in 100-day in-calf rate. This combines the effects of changes in both 100-day in-calf and 200-day not-in-calf rates. For dairy industries in countries outside Australia, such an economic benefit still needs to be determined.

18.4.2 Effects on milk production

Achieving improved body condition at calving affects milk yield and milk composition as well as fertility. Under Australian conditions, the effect of body condition at calving on milk production is presented in Table 18.5.

Table 18.5 Effect of condition score at calving on full lactation milk yield and milk fat content (Source: InCalf 2004a)

Condition score at calving	Milk yield	Milk fat
Less than 4.5	–105 L	–11%
4.5 to 5.5	–	–
More than 5.5	+79 L	+7%

Cows calving with condition scores of >4.5 produce more milk with higher milk fat content than those calving with <4.5. The opposite occurs in cows calving with condition scores of >5.5.

Using the example of changes in condition score profile in Table 18.3 (ie changing from 6:2:2 to 2:7:1 for condition score profile >4.5:4.5 to 5.5:<5.5), the milk production benefits for the herd over a full lactation can be calculated from Table 18.5 as follows:

1 Milk yield. There are four fewer cows with score <4.5 and one less cow with score >5.5. Improved milk yield is then:

$$4 \text{ cows} \times 105 \text{ L}) - (1 \times 79 \text{ L}) = 341 \text{ L}.$$

2 Milk fat content. Improved milk fat content is then:

$$4 \text{ cows} \times 11\% - (1 \times 7\%) = 0.37\%.$$

This extra milk produced can be easily valued and, in countries where incentive payments are given for milk composition, the improved milk fat can also be given a monetary value.

19

Overcoming environmental constraints to cow performance

This chapter:

Explains some of the important non-nutritional factors adversely affecting cow performance: genetics, heat stress, sanitation, animal health and the management of imported livestock.

The main points in this chapter:

- there is continuing discussion about the importance of genotype × environment interactions when selecting dairy genotypes for small holder dairy systems
- there are both direct and indirect effects of the hot and humid environment on cow performance, in that cows are routinely subjected to heat stress (direct effects) and forage quality is adversely affected by such climates (indirect)
- heat stress can be alleviated through cow shed design as well as management procedures to improve heat dissipation
- dairy effluent is an asset (fertiliser) as well as a major polluter
- small holder farms with tethered cows create many and varied health issues, such as shed hygiene and feet and leg problems
- when purchasing dairy stock from other countries, importers should recognise their specific requirements, which differ from those of local stock.

As the level of feeding in milking cows improves, so too does their susceptibility to other environmental constraints such as climatic stress, disease, pollution and poor herd management. For example, better fed and higher yielding cows are more adversely affected by heat stress, because of their higher internal heat production. This chapter may seem out of place in a manual on feeding, but since maintaining high nutrient intake becomes more difficult as it increases, environment has a major influence on the overall management of the high yielding herd.

19.1 Problems with exotic genotypes

The decision makers of most, if not all, South-East Asian countries place high credence on improving the genetic quality of their national herds. This has led to an influx of dairy stock from temperate areas, where they have been selected for many generations. According to McDowell (1994), over 25 countries in the 'low latitudes' (namely equatorial and tropical areas) are developing local milk industries based on imported dairy cattle, mainly Friesians from the temperate developed dairy industries in Europe, North America and Australasia. During the 20 years to 1995, 5 million Friesians have been exchanged in international trade, with half moved from temperate climate countries to those in the warm climate zones. All countries in Latin America have nucleus herds based on Friesians, as do 70% of the Asian and 66% of the African countries. The major exception has been India, which has based its genetic improvement program on indigenous dairy cattle and buffalo.

The importing countries are also being encouraged, often through financial subsidies, to use semen from progeny tested sires from countries of origin of these cattle, thus continuing the program of genetic upgrading of the temperate dairy stock. But with few exceptions, their low milk yields (2500 to 5000 L/lactation), high ages at first calving (30+ months) and long calving intervals (430 to 485 days) may not even support bank rates of credit for their purchase (McDowell 1994). Modern Friesians are genetically capable of producing their first calf at two years of age, then one every 12 months, yielding 8000 L milk over 300 days and milking for five lactations.

Ibrahim *et al.* (1992) reviewed 10 years of dairy development in Indonesia (East Java), concluding that increases had been mainly through imported cattle, but production gains were only at one-third of their genetic potential. The main reasons they listed would be relevant to many South-East Asian countries, being:

- lack of sufficient high quality feed
- poor adaptability of imported stock to local conditions
- poor housing and management
- too much attention of cooperatives to marketing and insufficient extension on cow problems
- failure to repay dairy credit in view of low productivity and poor milk price.

19.1.1 Genotype by environment interactions

Like all genetic improvement programs, be they livestock, cereal grains or fruit trees, the use of exotic gene stock needs to be accompanied with modifications to the environment. McDowell (1994) contends that this is not happening with dairy cattle because there still prevails the perception that Friesians, Jerseys or other improved dairy breeds can perform well on diets based on low to moderate digestible tropical grasses, in a foreign environment with temperature, disease, pollution and other production constraints.

Small holder dairying utilises a wide range of dairy stock in the humid tropics. These four types range from:

1. local, unimproved cattle with little breeding for milk production
2. crosses between local cattle and Zebu dairy breeds

3 crosses between local cattle and temperate dairy breeds
4 purebred temperate dairy breeds.

There is continuing discussion over the 'ideal' genotype for small holder dairying in the humid tropics. One rational approach is to consider the Genotype (G) by Environment interaction (ie G × E). Briefly, the relative performance of two genotypes depends on environment under which they are managed. When upgrading a national dairy industry from Type 1 above, is it better to base the industry on Types 2 or 3 and eventually on Type 4? More importantly, at what level of feeding and general herd management should the industry move from Type 3 to Type 4 cows?

The evolution of the dairy industry in the wet tropics of Central America is a good example of understanding how the breed must fit the system. There, the industry is now based on dual purpose cattle, rather than as it was 20 years ago, on traditional specialist dairy breeds such as Friesians. Cows are milked with the calf at foot and weaning generally coincides with the end of lactation. Income is generated from milk plus quality meat from yearling stock, rather than just the poor quality meat from cull cows as is usual in most dairy systems. This system has evolved because the dairy cows, being Zebu type, require calf presence to stimulate milk let down, they tend to dry off prematurely when daily calf contact ceases, and because milk substitutes and high quality calf concentrates are either not available or are prohibitively expensive.

No single tropical dairy type can be defined as the 'best'. The 'best' type will vary from local genotypes through to high grade Friesians. Unless heat stress is controlled, Vercoe (1999) believes that the very high yielding temperate breeds will always be less efficient than locally evolved ones. Such animals would be developed through crossbreeding local and exotic breeds then selecting within these populations for high milk yields. Similarly, it is unlikely that local breeds as purebreds will be the most profitable in all but the poorest of situations, where feed is inadequate, parasites and diseases are uncontrolled and levels of production barely fulfil household needs.

The genotype and its management must then be matched to:

- climatic conditions that exist
- available nutrition, whether home grown or supplemented with purchased feeds
- degree of challenge from parasites and diseases
- level of management skills
- availability and costs of labour to feed, milk and market the product, and its priority with other household demands
- availability of finance
- availability and access to profitable markets.

19.1.2 Specially bred tropical dairy genotypes

The ideal tropical dairy genotype is a small animal that yields high levels of milk and/or milk solids, annually produces a live calf (preferably a heifer) under simple small holder production systems based on tropical forages and with minimal environmental manipulation and low exposure to disease (Shamsuddin *et al.* 2003). Unfortunately such a genotype does not exist because high milk yields require high intakes of quality forages together with high internal heat production, hence management to alleviate heat stress.

Over the last 50 years, there have been various programs to develop tropically adapted dairy genotypes. These include the Jamaica Hope (80% Jersey, 15% Sahiwal, 5% Friesian) in the Caribbean and the Australian Milking Zebu and Australian Friesian Sahiwal in Australia. The objective of such breeding programs was to develop a stabilised genotype with the combined attributes of tropical adaptation and superior milk and reproductive performance. Although such stock would not exhibit the hybrid vigour of crossbreds, their progeny would be less variable in their physical and productive traits.

The Australian Milking Zebu program, which ceased in the 1970s, was based on Jerseys and Red Sindhi breeds, and produced a relatively small cow with low yields of high solids milk. Such a genotype would be ideal for many small holder industries, such as in Indonesia, where most of the milk is destined for industrial processing (hence the benefits of high solids content) and the feeding management is better suited to small cows with low maintenance requirements. However, when recently asked about the suitability of such a genotype, industry leaders in Indonesia considered the Australian Milking Zebu and Jersey to be less suitable because of the Friesian's better dairy beef sale value for bull calves or cull cows.

The more successful Australian Friesian Sahiwal program, which ceased in the 1990s, was based on Friesians and Sahiwal breeds. Such animals are currently in great demand throughout South-East Asia because of their performance in small holder dairy systems. Their Sahiwal ancestry provided the desired tropical adaptation to compliment the dairy performance of the Friesian. Preliminary discussions are now underway to resurrect this breeding program. Such a program would require a good database on the genetic variability of local Friesian populations, a shortfall in many South-East Asian countries where robust herd recording, and performance and progeny testing programs, are often lacking.

19.1.3 Problems of confinement

Compared to grazing, confinement creates specific problems, such as:

- restricting opportunity to seek comfort, for example, if only provided with cement floors
- creating problems of high humidity, which can be more detrimental than high temperature
- limiting opportunity for exercise, hence the need for routine hoof trimming
- increasing exposure to infectious diseases
- other health issues, such as mastitis and uterine infections when hygiene is poor during milking and calving
- creating problems of heat detection for artificial insemination
- requiring greater efforts into sanitation
- magnifying problems of social dominance
- increasing capital investment.

This chapter will concentrate on several of these issues, such as heat stress, sanitation, management to minimise animal health problems.

19.2 Alleviating heat stress

19.2.1 Direct effects on cow performance

The comfort zone for milking Friesian cows is 6°C to 18°C. Within this range, there are no measurable fluctuations in their physiological processes while the energy input to output shows good biological efficiency, in that all body processes will be functioning in their expected ranges. Between –5°C and +5°C, appetite will be stimulated while at the upper level, above 27°C, appetite is depressed and both biological and economic efficiencies decline. Above 24°C, Dry Matter (DM) intake decreases by about 3% for every rise of 1.2°C (McDowell 1994). The extent of the effects of temperature on appetite depend on:

- type and quality of forage – intakes of high fibre forages are more depressed at high temperatures
- type and quality of concentrates
- relative humidity – high humidity exaggerates the effect of high temperature
- stage of lactation – cows in early lactation are more susceptible to heat stress
- milk yield – high yielding cows are more susceptible to heat stress
- actual appetite.

Consideration should also be given to the type of protein source in the diet because depressed appetite and higher nitrogen excretion in the urine can lead to induced protein deficiencies. Although they recorded no difference in milk yield, Terada and Shoiya (2004) found that diets higher in Rumen Degradable Protein content reduced nitrogen loss in the manure and also body temperatures, respiration rates and the number of days to first oestrus in high yielding (<25 L/cow per day) Friesians subjected to heat stress.

When planning feeding programs, consideration should be given to the number of hours each day when temperatures exceed 27°C and relative humidity exceeds 80%; feed intakes will decline once temperatures exceed 27°C or higher for six hours. Furthermore, high body temperatures reduce the efficiency of rumen digestion and increase body maintenance requirements, further increasing the energy deficit. The net effect on feed intake depends on the number of hours each day below 20°C, which allows cows to cool and hence restore their heat balance.

The greater susceptibility of cows in early lactation to continuing levels of heat stress is clearly apparent from Table 19.1. In addition, heat stress adversely affects reproductive performance in three ways:

1. Acute stress can lead to embryo reabsorption while chronic stress upsets normal cyclic status, through hormonal changes, particularly if cows are exposed to six hours or more to temperatures above 27°C.
2. In late pregnancy, reduced foetal growth can also result from heat stress, leading to increased calf mortalities.
3. The intensity of expression of oestrus is depressed, in that oestrus periods are shorter (eg 12 v 17 hr) and although cows do cycle during hot periods, the percentage of those actually observed can be as low as 35% to 40%. This can be partly overcome by more frequent observations, such as every 6 hr rather than 12 hr.

Table 19.1 Effect of per cent days when temperature exceeds 27ºC for six hours or more on feed efficiency of Friesian cows

Feed efficiency is measured in milk yield/unit energy intake and expressed as proportion of that for cows in early lactation in the least stressful environment. (Source: McDowell 1994)

	Percentage (%) days >27ºC for 6 hr or more		
Stage of lactation (days)	**0–20**	**21–40**	**40–87**
0–100	1.00	0.87	0.73
101–200	0.96	0.91	0.88
201–300	1.02	0.91	0.85

The Temperature Humidity Index

The best single descriptor of heat stress is the Temperature Humidity Index (THI), as this combines temperature and relative humidity into a single comfort index. The higher the index, the greater the discomfort, and this occurs at lower temperatures for higher humidities (see Appendix 1).

For Friesians producing 20 L/d, a Temperature Humidity Index above 78 leads to a decline in milk yield. A Temperature Humidity Index of 78 occurs at 29°C with 50% humidity or at 27°C with 80% humidity. There is also a decline in milk composition (milk fat and milk protein contents) but this occurs at 1°C to 2°C higher than corresponding break points for milk yield (Davison *et al.* 1996). With regards reproduction, this declines before milk yield, namely at Temperature Humidity Index of 72, equivalent to 25°C plus 50% humidity or 23°C plus 80% humidity. The duration of oestrus drops from more than 10 hr to less than 8 hr. When planning strategies to minimise heat stress, it is then important to give priority to non-pregnant cows, usually in early lactation.

Symptoms of heat stress

There are many symptoms of heat stress, with those ones more relevant to cows in sheds shown below in italics. The initial signs are behavioural while the more severe ones are physiological, thus requiring immediate attention, to reduce their adverse effects on cow performance. In order of increasing severity, they are:

- body aligned with direction of solar radiation
- seeking shade
- *refusal to lie down*
- *reduced feed intake and/or eating smaller amounts more often*
- crowding over water trough
- body splashing
- *agitation and restlessness*
- *reduced or halted rumination*
- grouping to seek shade from other animals
- *open mouthed and laboured breathing*
- *excessive salivation*
- *inability to move*
- *collapse, convulsion and coma*
- *physiological failure and death.*

19.2.2 Indirect effects on cow performance

The greatest indirect effect of temperature is on feed quality and to a lesser extent seasonal changes in forage yield. Tropically adapted grasses have developed different pathways of photosynthesis to temperate species, allowing them to be classified as either C_3 (temperate) or C_4 (tropical). The C_4 grasses are more efficient at converting sun energy to forage dry matter, but at the same stage of plant maturity, they are usually of lower nutritive value, as shown below:

Table 19.2 Effect of plant physiology (C_3 or C_4) and age on digestibility and metabolisable energy content of forage grasses

Growth stage (days)	Digestibility (%)	ME (MJ/kg DM)
Young (45 d)		
C_3	69	9.7
C_4	58	7.6
Bloom		
C_3	64	8.8
C_4	45	5.6
Mature (60 d)		
C_3	54	7.1
C_4	38	4.3

Furthermore, increasing temperatures promote deposition of cell walls, reducing nutritive value, more so in C_4 than C_3 grasses.

Although not necessarily the direct result of higher temperatures, tropical soils are highly weathered, often with low pH (<5.3) and low in available soil nutrients. This can lead to low mineral contents in tropical forages, particularly phosphorus. Tropical environments are also more conducive to internal and external parasites.

Reduced forage quality and imbalances in feed nutrients invariably reduce milk yields and increase dry periods, due to delayed oestrus. Lengthy dry periods, exceeding 120 days, can produce overfat cows, increasing the likelihood of metabolic diseases following calving. In warm climates, calves will use 15% more energy to maintain heat balance than will their peers in temperate areas. The high humidity levels in the tropics, in conjunction with lower levels of calf care can also lead to higher incidence of respiratory problems, with long term effects on cow performance.

In practical terms, the stresses imposed by the direct effects of high temperatures are more apparent (eg changing behaviour) and can be more easily addressed. However, the indirect effects are less visible and may not be apparent until they become more serious with long-term consequences.

19.2.3 Designing cattle housing to minimise heat stress

Housing reduces heat load during mid day, where outside temperatures exceed 30°C, but the number of hours during the day when they exceed 27°C is the same both under a shelter and outside.

For cows producing 20 to 30 L milk/d and fed under corrugated iron during daylight with a sprinkler system, milk yield will not decline until the Temperature Humidity Index reaches 83 (ie at 33°C and 50% humidity or 30°C and 80% humidity).

Shed design

Assuming the sides of the shed are open to allow maximum ventilation, greater use should be made of the principles of air movement when designing the roof. Because hot air rises, and a herd of milking cows in a shed produces considerable heat, there should be an opening along the top of the roof, with a cap over it to restrict rain entering the shed. The roof slope should be greater than for feed sheds, namely 3 to 4º per 2.3 m, with the opening at least 50 cm wide, and the full length of the shed (McDowell 1994). Davison *et al.* (1996) recommend a roof slope of 33º (4 in 12), with a vent at the top of 30 cm plus 50 mm per 3 m of width for sheds with more than 6 m wide. An opening larger than 70 cm does not improve air flow. The lowest point of the roof should be 3 m from the ground. The steeper roof pitch increases air flow across and above the roof, thus creating negative pressure over the opening. This hastens the flow of air out the top as well as creating turbulence of air movement around the cows. If farmers are concerned about rain entering the shed through the vent, a gutter system can be installed below the ridge opening while the concrete floor can be sloped away from the feeding area.

A north–south orientation is preferable to allow the sun to dry underneath both sides of the shed. An east–west orientation is not recommended as the southern side will have less opportunity to dry out. Trees should be planted on the western side of the shed to reduce solar radiation. Grass, rather than cement, around the shed is also effective. Shade cloth, that blocks 90% of the light, can also provide protection provided it does not interfere with ventilation within the shed. I have seen mosquito netting in some regions, but such a decision would depend on recommendations of local veterinarians as to the potential animal health dangers of mosquito infestations. Eaves that extend one-third the side height will provide good sun protection.

An effective insulation of a cow shed, using egg cartons (Banbeung, Thailand).

The shed should be situated so that wind breezes are not blocked by any obstacles or other buildings. Ideally the shed should be on the highest ground possible, which will also be good for drainage of effluent, with other buildings located down wind on the site. There should be a minimum of four times the height of the nearest wind barrier as a horizontal separation. The ideal orientation, from a ventilation point of view, would allow the prevailing winds to hit the shed perpendicular to the side. This allows the wind to travel the shortest distance before exiting the shed, to improve the rate of air exchange and provide the cows with fresh air. The longer the shed, the more important is this perpendicular orientation to the prevailing winds. Other factors to consider are exposure of the outside stalls to sunshine, future expansion plans, cow flow, traffic flow and manure flow.

White-painted buildings reflect the solar radiation better than dark-painted buildings. Reflecting roof materials such as galvanised or aluminium are good long term investments. Insulation under the roof can reduce the heat load. Spraying water on the roof may only be effective in reducing roof and shed temperatures in areas with low humidity. One enterprising farmer in Thailand placed a layer of egg cartons underneath the roof as insulation against intense solar radiation (see picture on page 226).

Cooling fans

Fans can be arranged in many ways. A 0.5 horse power, 0.91 m diameter fan rated at 5 to 6 m^3/min will blow a distance of 9 m, while a 1.0 horse power, 1.21 m diameter fan rated at 9 to 10 m^3/min will blow a distance of 12 m. The direction of the fans should be with the prevailing wind. In wide sheds, the side-by-side spacing width of 0.9 m fans should be about 6 m, whereas 1.2 m diameter fans should be spaced 9 m apart. They should be positioned about 2 to 2.2 m above the floor. Fans should be tilted so they blow down to the floor directly under the next fan (about 30º from the vertical).

Exhaust fans, that do not require external power, may be worth considering to encourage greater heat removal through the roof. Household fans on stands may be used to improve heat loss from the higher yielding cows.

Sprinklers

Evaporative cooling is an efficient way of cooling cows, provided it is effective. In hot humid areas, sprinklers should always be accompanied by some form of ventilation.

Sprinklers have the disadvantage of increasing humidity and making the floor wet. Many studies show although they are beneficial in the short term, without forced ventilation, but they do not greatly improve feed intake, milk yield or expression of oestrus over a full 24 hr period. Their effectiveness depends on the humidity as the drier the air, the greater the decrease in temperature.

Sprinklers need to be suspended at least 2.3 m from the ground above the feed troughs with the water directed to the back of cows. The droplet size should be medium to large, depending on the humidity. It is important to install a filter at the beginning of the waterline and the sprinkler nozzles should be easily removed for cleaning. The nozzles should be directional, if possible, so that for major prevailing wind shifts, they can be adjusted to reduce wetting of feed.

Applying water to cows every five minutes reduces heat stress more than every 10 or 15 min. Ideally, cows should be sprinkled for 1 to 3 min, applying 1 to 2 mm of water per 15 min cycle. Using a timer system makes for easier management. The pipe size depends on the length and area of the shed to be sprinkled, the number of sprinklers and the flow rate. Use 32 mm diameter pipe for up to 30 m length or 51 mm diameter pipe for 60 to 150 m length. Nozzles should be spaced at twice the radius of their throw (eg every 2.4 m for nozzles with a 1.2 m radius).

Cows can be hosed down at the same time as their udders and teats are cleaned in preparation for milking, but this should occur at least 30 min prior to milk harvesting to minimise such wash down water contaminating the milk.

19.2.4 Management practices to minimise heat stress

Decisions based on respiration rates

Observing the behaviour of cows is important in deciding when to modify management. If respiration rates reach 70 breaths per minute, milk yield and reproduction may be compromised; this corresponds to 39°C body temperature, in contrast to a normal body temperature of 38.5°C. Higher yielding cows have faster respiration rates, because of the extra body heat production associated with higher feed intakes and milk yields .For such animals, respiration rates above 60/min are indicative of heat stress. Certainly, when they exceed 100/min, cooling strategies should be introduced. Improvements in milk yields of up to 3 to 5 L/d are possible through effective cooling strategies.

Respiration rates are easy for farmers to monitor. Ensure the cow is standing or lying in a relaxed state and preferably cannot see the farmer. To improve accuracy, the farmer could move his hands in time with abdominal movements until they are at a steady rate. Using a watch, he should count the abdominal movements for 10 seconds, repeating the exercise to ensure the count is consistent. Multiplying this by 6 will give the respiration rate in breaths per minute.

Monitoring respiration rates at various times of the day is a useful tool in assessing the suitability of sheds for milking cows. If rate exceed say 60/min in the morning, prior to the shed heating up, the cows would probably benefit from simple modifications in their environmental management. It is unlikely that major modifications in shed design could be justified, such as increasing roof height or pitch or shed height at the side, although serious consideration should be given to constructing roof vents. If minor improvements cannot be made in the shed's natural ventilation, such as removing obstructions to the prevailing breeze, fans and/or sprinklers should be installed.

One enterprising farmer in Vietnam constructed a small shelter away from the cow shed, which maximised natural ventilation through a high roof and its location, making best use of prevailing wind. Whenever he noted cows with high respiration rates, he hosed them down then moved them to the small shed to alleviate their heat stress.

Cooling a cow with a hose. Note the very low roof which would restrict air movement hence heat dissipation from cows in this shed. (Binh Duong province, Vietnam).

The easiest cooling method is to hose down the cow for several minutes. This should reduce respiration rates to 60/min. If the cow was severely stressed prior to cooling, with open mouthed and laboured breathing and excessive salivation, after being hosed down, she should soon return to the feed trough and start eating.

Allowing cows outside during the evening

Management systems can reduce heat stress by providing access outside the shed during the cooler afternoon and evenings, say after 5 or 6 pm. This will promote more effective conductive heat loss than inside, hence restore body comfort. This lounging area should:

- be located in a well-ventilated area
- be well drained
- have a dirt or gravel surface
- provide at least 5 to 10 m^2/cow
- incorporate water troughs
- incorporate troughs for feeding forages.

Moving cows outside following the afternoon milking could be combined with a change in routine milking management on small holder dairies, namely having a specific milking area within the shed, rather than milking cows where they are tethered. Milking parlours are easier to keep clean than the entire shed and the facilities can be sterilised periodically to improve milking hygiene.

It is difficult to monitor signs of oestrus in tethered cows. Providing cows with the opportunity to mingle in outside yards will allow them to seek out any cows on heat.

Feeding management

The digestion of fibre produces more heat in the rumen than the digestion of other carbohydrates. Therefore, offering most of the daily forages during the cooler periods of the evening will reduce internal heat production, particularly if the forages are high in fibre, which tropical forages usually are. Rations high in Rumen Degradable Protein can also depress appetite during periods of heat stress. Cows consume about two-thirds of their feed during the cooler evening and night. Feeding smaller amounts more frequently will reduce the likelihood of forages drying out and losing its palatability. The cooler the drinking water the better for both intake and temperature balance in the body.

When given continual access to feed, cows actively seek it from 5 to 9 am and again from 5 to 7 pm. Milkings should be finished prior to 6 am and 6 pm. Cows prefer feeding and watering following milking, after which they should be offered a dry surface on which to rest, preferably dirt. It is important that cows stand for at least 30 min after milking so the teat end can close to protect the teat canal from bacterial invasion.

Heat stress can lead to higher incidences of lactic acidosis (see Chapter 13). Depressed feed intakes will first, reduce saliva production which buffers the rumen against rapid changes in pH, and second, reduce rumen contractions, hence movement of digesta out of the rumen. Furthermore, rapid respiration rates for lengthy periods can reduce the concentration of sodium bicarbonate in the saliva, reducing its buffering capacity even further. In addition, cows may preferentially select concentrates and reject forages, predisposing them to acidosis.

Reduced forage intakes can decrease milk fat contents, while milk protein (or solids-not-fat) contents may fall due to lower dietary energy intakes. When the immune system of heat stressed cows is under greater strain, they are less able to cope with subclinical mastitis, which becomes apparent in higher levels of somatic cells in the milk. Not only would heat stress reduce milk yield, but its lower milk solids and higher somatic cell counts would reduce milk returns even further through lower unit returns for the milk.

Feed manger height is best when cows are eating with their heads down, to minimise wastage and obtain highest intakes. Cows produce 17% more saliva in this position compared to feeding with their head in a horizontal or raised position.

19.3 Sanitation and effluent management

Dairy farm effluent is both a liability and an asset to the small holder farmer. It is a liability so far as contaminating feeds, encouraging flies, and animal health issues, whereas its role in fertilising forages is an asset. Unfortunately, its full potential is not realised unless all the nutrients contained in the urine can be returned to the pastures. The nitrogen in urine is easily lost through volatilisation, unless it is stored and recycled to the pastures mixed with water.

19.3.1 Effluent as a liability

The management of animal manure represents a major health hazard on small holder farms, with the problem increasing with herd size, unless specific facilities are constructed. The problem is associated with several issues:

- quantity and quality of faeces and urine produced
- adequacy and frequency of removal
- storage in proximity to shed
- labour availability
- methods of storage and disposal
- value and use of manure
- community concern about pollution (smell as well as contamination of ground water and water courses).

The human health hazards are becoming more serious than previously realised, due to inadequate supervisory and sanitary measures. For example, in Thailand, a survey noted wastewater from small holder dairy farms constituted a considerable risk to public health because of its very high contents of inorganic pollutants and the presence of coliform organisms (Chantalakhana *et al*. 1998). Furthermore, there was considerable contamination of ground water supplies in nearby towns via waste water from local farms as well leaching from stored manure.

Not only is effluent management an environmental constraint to small holder dairying because of its potentially adverse influence on cow performance and cost of forage production, but also equally important, it can alter the livelihood of farmers themselves through community legislation limiting locations of farms. This can be particularly important for dairy farmers situated close to large towns and cities. In developed countries, considerable effort is spent in ensuring that farming activities are seen as 'clean and green' and this concept will no doubt extend into the humid tropics.

19.3.2 Effluent disposal systems

The floor should be made from concrete or easily washable material. It should be designed for efficient drainage with a good slope with wide channels for easy urine and faeces removal. A manure pit should be dug, large enough to hold the shed's manure produced over two or three days. A channel should be dug leading from the walking area to the pit and lined with concrete. The pit should be covered with a plastic sheet or banana leaves to reduce the sunlight, as this volatilises the nitrogen in the manure, reducing its value as a fertiliser. A fence around the pit will minimise risks to children and wandering stock.

As much urine as possible should be collected from the shed. It is advisable to use minimum water to initially wash out the manure drains, then direct the main washings from the floor into another pit or direct out to the forage producing area. An alternative effluent system is to all manure and shed washings to flow into the one pit which is equipped with a manure pump to direct the effluent to the forage producing area, along gutters between the rows of plants.

19.3.3 Effluent as an asset

Cows, on average, produce daily: 46 kg of manure, from 32 kg faeces and 14 kg urine, containing 0.15 kg nitrogen, 0.04 kg phosphorus and 0.08 kg potassium (Choi *et al.* 2004). Its use when recycled on the farm as fertiliser for forage production is discussed in Chapter 8.

19.4 Management problems specific to small holder farms

19.4.1 Animal and human health

High standards of sanitation are required at all times to prevent rapid spread of infectious diseases in both young stock and milking cows. The most effective way of destroying disease carrying microorganisms is cleaning and disinfecting (sterilising or sanitising). However, the latter has little effect unless the surface is first cleaned. The best cleaner and disinfectant depends on the type of surface.

Government veterinary services must maintain surveillance of infectious or notifiable diseases, such as rinderpest, foot and mouth disease, and contagious pneumonia, through vaccination and quarantine measures. However, as farms become more intensively managed, non-infectious diseases become more important role in limiting cow performance. These could be called disease-causing risk factors such as undernutrition, poor hygiene and other management factors affecting herd productivity.

Farmers are only interested in herd health programs when the link with production is clear, such as declining milk yields, increasing mortality and poor reproduction. Mastitis, for example, is hard to manage because the subclinical form is very prevalent, difficult to detect and causes higher milk losses per affected cow. It is often difficult to incorporate economic parameters in such programs because of the few stock, and hence the influential impact of the performance of each animal.

There are many diseases that can be transferred from intensively managed livestock to humans. These include *Salmonella* (and other calf scour-causing microorganisms), ringworm, mange (and other skin diseases) and *Leptospirosis* and *tuberculosis*. Children are particularly susceptible because of their affinity to young calves, and their poor understanding of human hygiene. Another potential hazard for young children are veterinary drugs and chemicals used for cleaning or sanitation. These should be stored in a secure place.

19.4.2 Feet and leg problems

Feet problems

These can be caused the environment (continuous wet floors, uneven or broken cement), poor sanitation, infectious organisms or nutritional imbalances. With tethered cows, annual trimming can extend herd life by at least one year. There are recommended dimensions for hoof claws and many confined herds have cows outside these recommendations, which are:

- toe angle, 40° to 50°
- toe length, 1st lactation 60 to 70 mm; later lactations, 60 to 80 mm
- diagonal length from top of heel to end of toe, 140 to 150 mm.

Overgrowing will cause the toe angle to decline and foot length to increase, placing more weight on the heels, thus creating discomfort and walking difficulty. The rear feet appear to be more subject to disorders. High levels of concentrate feeding can lead to a condition called laminitis, which causes softening of the tissue between the claws of the feet. Trauma injuries can occur on uneven concrete floors, leading to swollen hocks, knees or even hips.

Bruised soles

Inside the hard, outer layer of the hoof wall and sole, there is a sensitive layer rich in blood vessels and nerves. If a cow stands on a stone, or some other small hard object, its sole bends upwards over the stone, severely squeezing the sensitive layer. This can cause bleeding within the claw, and subsequently pressure, pain and lameness.

Bruising is identified in a well-cleaned sole as pink or dark red flecks. Very soft feet, due to moist or wet conditions, are more prone to bruising. If the sole is thin due to excessive wear, it offers less protection to such damage. Such wear can result from standing on very rough concrete floors or animals being bullied by dominant animals or even excessive turning on floors when on heat.

Bruising will repair with time but rest is important. Particularly severe bruising may need some form of relief from the pressure of body weight and walking. If bruising is largely confined to one claw, glue-on plastic or leather lace-up shoes can be fitted. Preventative measures include ensuring floors are not too abrasive, with all stones and broken pieces of concrete removed. Hoof trimming will also assist. Foot baths containing formalin (for hardening hooves) or sprays of zinc sulfate solution (for treating sore feet) are also useful.

Providing cows with soft bedding, such as a dirt lounging area or rubber mats improves cow comfort as well as reduces feet and leg problems. Other factors influencing sore feet resulting from acidosis are discussed in Chapter 13.

Assessing cow lameness

Lameness is an increasing problem in both grazing and housed cows, with economic implications. Locomotion scoring from 1 to 5 (for increasing lameness) is a new tool (Sprechter *et al.* 1997), which provides a quick measure of the cow's ability to walk normally (Table 19.3). Observations should be made of cows standing and walking (gait), with emphasis on their back posture. Observations should be made on a flat surface that provides good footing for cows.

Locomotion scores of individual cows can be used to select cows for hoof examination before they become clinically lame. Those with scores of 2 and 3 are considered subclinically lame and their hoofs should be examined and trimmed to prevent more serious problems. Scores of 4 and 5 represent those cows clinically lame. The higher the lameness score, the greater the reduction in feed intake and milk yield and the poorer the body condition. For example, a score of 4 can reduce dry matter intakes by 7% and milk yields by 17%, while a score of 5 can reduce dry matter intakes by 16% and milk yields by 36%.

Table 19.3 Locomotion score guide based on observations of back posture and behaviour when walking (Source: Sprechter *et al.* 1997)

Score	Clinical description	Back posture	Assessment
1	Normal	Flat	Cow stands and walks with a level back. Gait is normal.
2	Mildly lame	Flat or arch	Cow stands with level back, but arches when walks. Gait is slightly abnormal
3	Moderately lame	Arch	Stands and walks with arched back. Short strides with one or more legs.
4	Lame	Arch	Arched back is always evident and gait is one deliberate step at a time. Cow favours one or more legs/feet but can still bear some weight on them.
5	Severely lame	3-legged	Cow demonstrates an inability or extreme reluctance to bear weight on one or more limbs/feet.

19.5 Importing cows and heifers from other countries

Most countries with small holder dairy industries have development programs involving increasing cow numbers and genetic quality through importing dairy stock, usually Friesians.

The major oversight by both the importers, whether private investors or government organisations, and the farmers for whom these stock are destined, is not 'preparing the environment' for the imported stock. The greatest shortfalls are:

- lack of knowledge of quality of local feedstuffs, particularly forages
- lack of understanding of their nutrient requirements for acceptable performance, to reduce stress
- low skills of local labour to handle high level of technology in genetics of imported stock
- poor sanitation practices for manure disposal, fly control and drying of all floor surfaces
- lack of sufficient quarantine, to minimise spread of disease while heifers are still susceptible
- lack of knowledge and management skills to address problems during calving
- difficulty of supplying optimum diet during early lactation to reduce live weight loss, hence lactation anoestrus
- minimising environmental stress during early lactation so newly calved heifers can cycle normally after two months.

Other factors to consider include:

- selection of the most appropriate heifers prior to transport
- providing good calf and heifer rearing management so calves from imported heifers are well grown and have the opportunity to express their true genetic merit when milking.

19.5.1 Genetic merit of imported stock

The decision on the most appropriate type of stock to import should be seriously considered. Selection of high-genetic merit heifers or cows to import means farmers will need to improve their feeding management to provide sufficient energy to allow these animals to better express their superior genetic merit. This is very important in early lactation when such stock are expected to cycle as well as to produce high levels of milk.

Cows can produce the same milk yield in early lactation with whole body energy balances ranging from +4 to –25 MJ/d. This is the energetic equivalent of 0.8 L milk to build body reserves or to lose the energy derived from losing of 0.8 kg/d of body weight. Clearly cows that are genetically 'programmed' to lose excess weight in early lactation are less desirable in small holder systems where feed shortages are all too common.

Perhaps it would be wiser to import stock of lower genetic merit and then feed them to produce less milk, but at least improve their chances of getting back in calf within 100 days post-partum. The best farmers in Australia can achieve 58% 100-day in-calf rates (Morton *et al.* 2003), compared to only 40% in a well-managed farm in Vietnam (Moran and Tranter 2004).

It is not uncommon for South-East Asian importers of Friesian heifers from Australia to request '5000 litre heifers' (ie heifers likely to produce 5000 L during their first lactation on their home farm). It is highly likely that, once in their new farm in South-East Asia, such animals would be capable of producing only 2000 or 3000 L during their first (and even later) lactation given the existing feeding management. If such animals managed to produce 25 L/d in peak lactation (as a starting point to achieve their 5000 L first lactation yield), their daily energy deficit would be highly likely to impair their 100-day in-calf rate.

19.5.2 Importing young heifers

The high cost of importing pregnant heifers makes alternative methods of increasing cow numbers feasible. For example, consideration could be given to purchasing heifer calves, growing them out for say 6 to 12 months in the exporting country prior to their importation. Granted, this will only supply one animal, compared to the heifer plus embryo when importing pregnant heifers, and delay initiating income, but this will allow an additional 12 months for adaptation to the new environment, prior to calving.

Such adaptation includes adjustment to the climate, feeds, management regime and developing resistance to local parasites and diseases. Over the short term, importing pregnant heifers may give higher returns, but for the long term, importing younger heifers may be more economic (McDowell 1994).

This discussion does not even consider the greater susceptibility of high-genetic merit cows to their physical environment. High milk yields, through increased feed intake, generate more internal heat, thus requiring a less stressful environment to dissipate such heat. Therefore, unless such cows are allowed to regain their normal heat balance, their appetite will fall, hence they will eat less. The only way they can produce milk close to their desired level is by partitioning body reserves towards milk synthesis, thereby increasing energy deficits through greater live weight losses.

It is then likely that these animals will be unable to produce their target milk yields and will not easily get back in calf. Such animals are generally more susceptible to other constraints of the tropical environment. This further increases their likelihood of being culled as non-productive animals. Even if their high purchase cost and their 'status' as exotic cows reduces pressures to cull them, they will become poorer investments compared to locally adapted, and hence stock with less production potential.

19.5.3 The renewed relevance of embryo transfer technology

The practice of Multiple Ovulation and Embryo Transfer is only slowly being accepted in Western dairy industries as another method to more rapidly improve genetic merit, albeit mainly in the pedigree dairy industry. The general consensus is that this technology is not yet a sound economic approach for widespread use in dairy operations whose entire or main business is selling milk (McDowell 1994).

However, for large-scale multiplication of national herds, where genetic progress is less of an issue, and where in their new country as lactating cows, imported heifers cost two to three times more than their original purchase cost, multiple ovulation and embryo transfer may have an economic role. Countries such as China are assessing its relevance to national industry development.

19.5.4 Satisfying customer demands

What the customer wants is often not what the customer needs. Furthermore, what the customer needs may differ even from what the customer gets (Moran 2005).

What the customer wants

Generally, the importer wants firstly, to increase herd numbers in the region being serviced, and secondly, to improve the genetic merit of the milking cows in that region. The first can be achieved by importing any type of dairy animal that will produce milk and reproduce under the existing environmental and production constraints.

Depending on the market demand for the raw product, the imported stock can produce:

1 relatively low quantities of high solids milk, if it is destined for industrial processing to yield dairy products such as milk powder
2 higher yields of milk with lower milk solids, if it is destined for consumption within a few days or even if it is to be processed into long shelf-life products to which imported milk powder can be added.

Milking cows must also routinely produce calves, either as herd replacements or for sale, plus have a disposal value as a cull cow. This can influence the preferred breed because purebred and crossbred Friesians have a higher value for dairy beef than Jerseys or Zebus.

The purchaser may have a set of specifications, some of which are poorly related to production, such as coat colour (eg four white feet and white tip of tail) and udder shape (particularly for cows being milked by hand rather than machines). Large body size should be less of a selection criterion with poorer feeding management and may even be negatively related to performance and longevity in some small holder milking herds. It should be explained to the purchaser which of these selection criteria are the most relevant to the farming system to which the stock will eventually be subjected.

Some contracts may require printed proof of the cow's ancestry, such as the pedigree of its Friesian sire and proof of some stipulated minimum milk yield of its dam. As many of the farmers supplying export stock do not record such data (whose value to the importing country must frequently be questioned), this will limit the number of stock acceptable for export.

Rather than seeking pregnant heifers, some importers prefer younger virgin heifers, with minimum live weights, such as 9 to 16-month-old Friesian heifers weighing from 200 to 360 kg.

What the customer needs

The purchaser usually requires an 'all round performer'. Initially the imported stock may be well managed but eventually their progeny will enter the general dairy population, hence be subjected to more normal farming systems. The ideal imported heifer and her progeny should then be able to perform equally well, compared to local stock, in both well and poorly managed systems. Therefore, heifers from 'average' rather than 'superior' dams may be more suited to purchaser requirements.

There is continuing debate regarding whether it is better to source genotypes to suit existing systems rather than try and 'fit the system' around the genotype. The challenge of the importer is to match the genetic merit of the stock to those farms most likely to benefit from it.

Certainly the Australian Friesian Sahiwal appears better suited to the humid tropics than the purebred Friesian. Jerseys are a more tropically adapted breed than Friesians, with their smaller body size, black skin, higher density of sweat glands and lower internal body heat production, because of their lower productivity. As well as their suitability, there is increasing interest in exporting countries, such as Australia, in utilising some of the production attributes of the crossbred Jersey × Friesian. These animals may have potential as export heifers, at least until more Australian Friesian Sahiwal become available for sale. Brown Swiss is another breed considered to have tropical adaptation features.

What the customer gets

There is increasing concern in many developed temperate dairy industries that current levels of heifer attrition, through export sales, is eroding the genetic quality of their dairy stock. Replacement heifers are required firstly, to expand these local industries and secondly, to allow adequate culling of inferior stock. Such concerns increase sale prices for export heifers, impacting on supplies of suitable stock to meet export demands.

Unlike in other countries, many Australian dairy farmers do not use Friesian bulls or semen over their replacement heifers, often preferring Jerseys or Angus breeds because of small Friesian heifer size at mating. Furthermore, such crossbred progeny have high sale value as week-old calves. The use of Jersey sires is likely to be greater, with current interests in crossbred milking cows, thus reducing the availability of purebred Friesians, the current genotype of choice for export.

Over the last five years sourcing stock for export has been made easier as farmers offload their excess replacements during droughts or when leaving the industry. However, such supplies are abnormal compared to more normal years, when farmers require 25% to 30% of their heifers as herd replacements. How long the current rate of supply of dairy heifers will be available to meet the increasing demands for export must also be addressed.

20

Future developments in feeding management in the humid tropics

This chapter:

Discusses some of the priority areas for research and extension in dairy feeding management.

The main points in this chapter:

- the advances in feeding management achieved in temperate dairy systems over the last two decades have not been replicated on tropical small holder farms
- it is important to determine optimum stocking rates for each small holder farm and not exceed them
- cows use nutrients, not feeds, to produce milk. Therefore, knowing feed quality then feeding for production targets are the two major elements of good nutritional management
- whole crop maize silage or greenchop is an ideal feed to incorporate into dairy feeding systems
- profitability depends on marginal milk responses and marginal feed costs. These are the additional milk produced from the next kilogram of feed and its cost
- the causes of poor farm profitability can be diagnosed, using nine key questions on feeding management
- it is energetically more efficient and generally more profitable to feed fewer cows better.
- attention to improved genetics should only be considered once feeding management can adequately supply the required additional nutrients
- cassava and cowpea hays have been incorporated into an innovative dairy feeding system
- research priorities should be directed more towards risk minimisation rather than just to income generation
- the priority list for future dairy nutrition research and extension needs is presented.

Over the last 20 years of dairy research, development and extension, many Western countries have produced sophisticated dairy production systems. Herd sizes have grown, efficient feeding systems have evolved and many farmers routinely test their cows for milk production, composition and quality and for mastitis. They then use this information for making decisions on culling milking cows and for breeding genetically improved stock. High labour costs have led to much mechanisation, such as machine milking and forage conservation, while grazing cows can harvest their own forages far more efficiently than can farmers. Low population pressures, hence relatively cheap land, has allowed farms to expand in both size and cow numbers.

Unfortunately this has not been the case for small holder dairy farmers in most countries in South-East Asia. Being in the tropics, feed quality suffers from high temperatures and strongly seasonal rainfall patterns. Dairy cows are temperate animals with thermoneutral (comfort) zones closer to 10°C than to 30°C. Furthermore, high humidities reduce feed intakes which exaggerate the adverse effects of high fibre forages on appetite. A good measure of heat stress, the Temperature Humidity Index, shows milking cows in the lowlands of the humid tropics to be in the 'high stress' and 'reduced performance' zones for much of most days throughout the year. Many dairy specialists argue that potentially high performance dairy breeds, such as Friesians, may not necessarily be the best dairy cattle genotype for tropical regions, except in highland areas or those with low humidities.

There are many socioeconomic reasons why the efficiency of small holder dairy farming has not greatly improved over the last two decades. Granted, numbers of cows has greatly increased in most South-East Asian countries, largely through government support for social welfare and rural development programs. The increased demand for milk (accentuated through school milk programs) and the concept of national food security are the driving forces behind dairy development initiatives. However, in terms of feed inputs per litre of milk produced, improvements have been slow.

Much of the technical progress in Western dairy countries has not been relevant to South-East Asia, and some of it may have been unwisely transplanted. Commercial interests selling 'improved genetics' often do not explain the need for 'the feeding to go with the breeding'. Granted, milking cows must get back in calf to keep producing milk, so good herd fertility is essential. However, poor early lactation feeding will not allow these 'improved' cows to express their potential for good fertility.

This chapter discusses many of the key obstacles to improving current feeding management practices that face institutional managers, educators, dairy advisers and dairy farmers.

20.1 Determining optimum on-farm stocking capacities

Very rarely do farmers and advisers calculate the optimum stocking capacity of any one farm. Unfortunately herd sizes are usually the result of 'trial and error' whereby farmers increase cow numbers until they become too expensive to feed or their milk yields decline below acceptable levels. Estimated farm forage yields must be taken into account when determining how many cows and young stock can be fed adequately from a particular sized small holder dairy farm.

The following scenarios are to assist in such a mathematical exercise. To calculate stocking capacitities, a series of assumptions have to be made:

1 Forages contain 15% DM (not the 20% as often assumed) and yield:
  - 10 t DM/ha per year (67 t fresh/ha per year) under poor management such as only fertilising with cow manure, no supplementary irrigation, no harvest program
  - 20 DM/ha per year (130 t fresh/ha per year) under typical management such as fertilising with cow manure and limited inorganic fertiliser, typical approach to forage management
  - 30 t DM/ha (200 t fresh/ha per year) under good management such as fertilising with sufficient inorganic nitrogen and phosphorus fertilisers to match forage requirements, water supplies and harvest program for optimum yield and quality.

2 The management allows for forage conservation to transfer wet season excess pastures for dry season feeding.

3 Small holder farmers use their forages to rear replacement heifers as well as feed their adult cows, when lactating and dry. Farmers rear 20% of their milking herd as replacements, which first calve at 27 months of age.

4 An adult cow milking unit is, therefore, one adult cow plus 20% of a replacement heifer.

5 In year-round calving systems, only 75% of the adult cows are milking at any one time. Therefore each year, adult cows milk for 275 d and are dry for 90 d.

6 The forage feeding program allows for feeding:
  - 50 kg/d of fresh forage (7.5 kg DM/d) to milking cows
  - 30 kg/d of fresh forage (4.5 kg DM/d) to dry cows
  - 20 kg/d of fresh forage (3.0 kg DM/d) to heifers, averaged over a full 24 mth of feeding weaned stock

7 Concentrates and purchased forages are fed to provide the balance of the diet to achieve target milk yields. However, such feed inputs are not relevant to these scenarios.

The annual forage requirements for each milking unit are then:

- 13,750 kg fresh (or 2065 kg DM) for the milking cow (71% of total)
- 2,700 kg fresh (or 405 kg DM) for the dry cow (14% of total)
- 2,920 kg fresh (or 438 kg DM) for 20% of a replacement heifer (15% of total)

or a total of 19,370 kg fresh (or 2,905 kg DM) for each milking unit.

The stocking capacities, or numbers of stock that could be fed from one hectare of forage, are presented in Table 20.1.

Table 20.1 Optimum stocking capacities for small holder dairy farms with different levels of forage management

One milking unit is one adult cow plus 20% of a replacement heifer. Assumed forage intakes: 7.5 kg DM/d for 275 d/yr for milking cows; 4.5 kg DM/d for 90 d/yr for dry cows; 3.0 kg DM/d for 365 d/yr for 20% of a replacement heifer.

Level of farm forage management	Poor	Typical	Good
Forage yield			
t DM/ha year t fresh/ha year	10 67	20 130	30 200
Milking units/ha forage	3.4	6.9	10.3
Adult cows/ha forage	4.0	8.1	12.1

Therefore, to provide sufficient quality home grown forage for a well-balanced diet to all stock, the typical 0.5 ha small holder farm should have no more than two to five milking cow units, that is two to five adult cows plus one replacement heifer, depending on management of the forage production area.

This is further evidence that farmers should feed fewer cows better. With increasing dependence on purchased forages, feed costs are invariably more expensive and dietary quality generally poorer than when basing dairy production systems on home-grown forages.

20.2 Research and extension priorities in feeding management

20.2.1 Variability in nutritive value

Cows use nutrients, not feeds, to produce milk. There is little point in producing large amounts of forages if it is too low in quality to produce milk. It may be suitable for dry cows or growing out young stock, but the best feed should be reserved for milking cows, with the higher producing cows receiving the best quality.

This manual has highlighted the importance of knowing the nutritive value of the variety of feeds used for small holder dairy production. The range of growing conditions of forages means their energy, protein and fibre contents can vary widely. Not only do these depend on the stage of maturity at harvest, but the soil nutrient status, which is largely affected by the use of fertilisers (both inorganic and organic), also has a marked effect. Many of the by-products fed originate from a range of agro-industrial processes, meaning that they can also vary widely in feeding value.

Without good knowledge of their nutritive values, it is not possible to develop optimum feeding strategies, particularly for forages. Feeding strategies should be based on the cost of feed nutrients, those that are most limiting cow performance. On the whole these are energy, although if protein supplies do not balance the energy, protein also becomes a limiting nutrient. Hence, cost per unit of energy or protein should be the major decider, in conjunction with Neutral Detergent Fibre content, when purchasing feeds to overcome short falls in forage quality and quality. This is particularly important during the dry season as supplementary forage prices will increase with demand. It may be cheaper to purchase dry season supplements at other times of the year, provided quality does not deteriorate during storage. Certainly, using silage to store wet by-products as well as forages is one way to maintain feed supplies during such periods.

Computer aids to ration formulation are described in Chapter 12, with one particular program, named DRASTIC worthy of particular mention. DRASTIC is the abbreviation for **D**airy **RA**tioning **S**ystem for the **T**rop**IC**s, a program developed by tropical dairy specialists in the United Kingdom.

The program uses qualitative and visual indicators in forages that can be undertaken easily by farmers, such as leaf: stem ratio, days after defoliation, forage colour, pest or disease damage, odour, moisture content, length of chop and general assessment. These are related directly to actual measures of energy and protein contents for specific forage species of grasses, legumes, silages and hays/crop residues which are then used to calculate nutrient intakes, to predict cow performance. The program even allows for grazing in predicting forage intakes.

DRASTIC then provides a tool to assist rationing dairy cows where access to technical knowledge is limited but practical experiences are considerable. The program is freely available from Dr Peter Stirling at drastic@stirlingthorne.com or www.stirlingthorne.com/about_drastic.html.

20.2.2 Seasonality of quality forage supplies

For cows to produce milk throughout the year, they must have a year-round supply of nutrients, particularly forages. In much of South-East Asia, rice straw is the basis for feeding livestock, particularly those without high nutrient requirements. Milking cows have high nutrient requirements, too high to be economically viable unless alternative, much better quality dry season forages are readily available. Even chemically treated rice straw is hardly, what many nutritionists would call, a 'milking feed' (see Chapter 10).

The location of farms can influence their success in producing profitable milk, particularly when dry season forages cannot be grown or sourced locally. For example, Karnjanasirm *et al*. (1999) described a situation in Thailand's Nakorn Pathom province where the least successful dairy farmers were those with insufficient areas for growing forage. They had to source forages, mainly maize stover, from a long distance, making the feeds very expensive. In comparison, farmers in North-East Thailand who had larger areas for forage cultivation benefited more from forage than did farmers with smaller areas (Bunyanuwat *et al*. 1995). Most innovative small holder dairy farmers try to establish their own pasture to be less dependent on purchased forages.

As many peri-urban farmers have discovered, producing milk without adequate quality forages requires high levels of concentrates. Milk composition can suffer unless there is a correct balance of forages and concentrates. Low fat content, which is quite common in small holder dairying, is a syndrome of low intakes of quality fibre. Low protein, which is even more common, is an indicator of low energy intakes, and hardly influenced by protein intake. Poor milk composition costs money through reduced unit price of milk (see Chapter 17). Therefore, improper feeding management costs both in terms of milk volume and composition.

In some countries, where labour has little value, virtually every available source of forage is harvested, generally by hand, for livestock feeding. Such countries even have 'grass markets' where such forage harvesters can sell their wares, be they native grasses or tree leaves, to small holder farmers as a mainstay fodder source for their stock. In most countries there are areas in rural regions, for example beside major roads and railways or around rice paddy fields, where forages could be readily harvested for many months of the year. But as labour becomes more costly, such forages become too expensive to be cost-effective in small holder systems.

20.2.3 Maize and its by-products

Over the last two decades, maize (or corn) is producing increasing tonnages of milk throughout the world. Not only is maize forage and forage by-products integral in many dairy systems, but the grain and grain by-products are too (see Chapter 9). Maize is the only forage that does not decrease in quality as it matures, because the deposition of grain on the cob compensates for increasing fibre levels in the leaf and stem. Granted protein levels are not high, only 6% to 8% in whole crop silage; however these can be easily improved through incorporating urea with the silage or greenchop.

As maize is a basic feed for many communities, research attention is being given to improving the nutritive value of the maize stover. The stover is that part of the plant left over following harvest of the cob for grain or sweet corn. The plant is less mature when harvested for sweet corn than for grain, making sweet corn stover is a better quality forage then corn stover following grain harvest.

To produce milk from a moderate-quality forage such as maize stover, additional nutrients must be included from energy and protein-rich concentrates. If the whole plant (including the cob) is chopped and fed to milking cows, fewer concentrates are required. Whole crop maize silage has an additional feature in that it has a low dietary cation–anion balance (see Chapter 13), making it an excellent forage for feeding dry cows just prior to calving, as a precaution against milk fever.

The Nong Yai feed centre managed by the Banbueng dairy cooperative in southern Thailand. This centre stores maize silage in tower and pit silos and prepares total mixed rations for delivery to cooperative members.

Inside the Nong Yai feed centre where the mixer waggon directs rations into bags for direct delivery to farmers. (Banbueng, southern Thailand).

In Thailand's Banbueng province large areas of maize, destined for whole crop silage, are grown by dairy cooperatives, ensiled in large cement towers or bunkers, then sold to individual farmers at cost price (at 1.25 Bt/kg fresh). This approach is proving very profitable in increasing local milk production through a relatively cheap year-round source of quality forage. Even though the forage may appear expensive, a true cost comparison should be to calculate milk income less feed costs for the various alternative dry season rations (see Table 17.6).

A cooperative dairy farmer member receiving a 500 kg bag of maize silage (Banbueng, southern Thailand).

As well as selling maize silage, in large (500 kg) hessian sacks, the Banbueng cooperative has a feed centre where they prepare a variety of total mixed rations, based on the silage, for direct sale to small holders to feed their cows in various stages of lactation (see photograph on page 244). The maize silage is particularly useful in restoring body condition on cows during the late lactation and dry period. The cooperative also has a calf rearing unit and yards for heifer rearing close to the feed centre, thereby allowing the farmers to stock their farms predominantly with milking cows, hence to concentrate all their efforts in producing milk.

20.2.4 Milk to concentrate ratios in production rations

Many dairy advisers in South-East Asia use a general 'rule of thumb' that for every 2 L of milk produced, farmers should feed 1 kg concentrate. This is a safety measure because of lack of knowledge on the nutritive value of the feeds, particularly the forages. It also provides supplemental energy to cows when fed only limited amounts of forage. In any dairy system, whether in temperate grazing systems or South-East Asian small holder systems, the principles for feeding milking cows should be:

1. feed sufficient quality forages first, then
2. supplement with concentrates, which are
3. formulated to overcoming specific nutrient deficiencies
4. to achieve target milk yields.

With knowledge of the feeding value of the forages and concentrates, and their costs, more objective hence better decisions, can be made on how much concentrates should be fed to achieve target milk yields. Granted this requires more knowledge and greater effort than following the 'feed 1 kg concentrate per 2 L milk' rule, but such decisions can greatly reduce feed costs, hence improve profitability, when expressed as milk income less feed costs.

In Chapter 11, Table 11.6 listed the level of concentrates required to achieve target milk yields with varying forage qualities. These feeding decisions have been converted into milk:concentrate ratios in Table 20.2. When cows are fed better quality forages, more milk is produced per kilogram of concentrate fed. The 2:1 (1 kg concentrate:2 L milk) rule is only applicable with very low quality forages, namely those with Metabolisable Energy contents of 7 to 8 MJ/kg DM.

Table 20.2 Milk:concentrate ratios (L milk produced/kg concentrate fed) to achieve target milk yield in cows fed forages of varying quality
dry matter (DM); metabolisable energy (ME). (Source: Devendra 1975)

Milk yield (L/d)	Forage quality (MJ of ME/kg DM)			
	7.3	8.2	9.0	9.9
6	1.8	8.6	–	–
10	2.0	4.0	12.5	–
14	2.1	2.9	12.7	46.7
18	2.2	3.0	6.0	25.7
22	2.2	2.9	4.1	12.9

Milk production is very responsive to nutrient intake. Among livestock producers, dairy farmers are very fortunate in that their cow's milk yield today is directly affected by their feeding management yesterday. No other type of livestock provides such a rapid feedback to herd management. Once farmers set their target milk yields, so long as they are realistic to their farming system, they can monitor their success or failure in achieving these by gradually changing one of the feeds in the cows' ration. If the additional milk produced, as feeding levels are improved, returns more than the additional feed inputs, then that was a profitable management decision.

Farmers can change their feeding program, but only one feed at a time, say once per week then note the milk response. They should also note changes in other feed inputs. For example, if they increase concentrates and find cows eat less forage, and know the cost of energy or protein in the various feeds, they can then decide on the most profitable combination of these feeds.

20.2.5 Marginal milk responses

The definition of substitution in Chapter 11 is 'the reduction in forage dry matter intake per kilogram supplement DM offered'. This is a marginal measure of change because substitution rates change as forage and concentrate intakes vary. This is a very important concept in biological responses, particularly for milking cows. Biological (output/input) ratios are rarely constant, varying with changes in inputs. So too with milk output.

As discussed in Chapter 11, better fed cows have poorer milk responses than do those less well fed. Hence, their marginal milk response decreases with level of feeding, and so does their milk production. Partition of dietary nutrients into body reserves, rather than towards milk synthesis in the udder, is a major reason why better fed cows have poorer marginal milk responses. Provided some of this redirected energy is repartitioned back into milk in the following lactation, it is still a useful contributor to the cow's production. This is why it is important to fully understand, from Chapter 11, that milk responses to changes in feeding management are both immediate (show up next week) and delayed (show up next year).

20.2.6 Marginal cost of production

In Chapter 17, it was explained that high yielding cows may need to be fed better quality rations as well as more total dry matter. This may mean that every kilogram of dry matter may be more costly to grow or purchase. Forage quality depends on stage of maturity, with frequently harvested forages having higher nutritive value than those less frequently harvested. Such a measure is based on dry matter, not fresh weight, because immature forages have lower dry matter contents, meaning that more fresh forage must be fed to achieve the same intake of dry matter. If this then means that less is harvested, because the forage is cut earlier and because more of it must be fed to achieve the same intake of dry matter, then each kilogram of dry matter is likely to cost more to grow. However, if more milk is produced from each kilogram of forage, then earlier harvesting may be an economic decision.

Better quality concentrates are also more costly to purchase. For example, Table 10.2 details two grades of rice bran (with 11 v 8 MJ/kg DM of ME and 14% v 8% CP). From Table 17.1, rice bran Grade 1 (or A) in Thailand has been costed at 4.5 Bt/kg fresh whereas Grade 2 (or B) may only cost 1 or 2 Bt/kg.

Feeding more expensive feeds increases the cost of production. For cows to produce more milk they may have to be fed more expensive feeds, and hence the marginal cost of production increases. This additional cost is offset by a reduced maintenance component, hence converting more feed nutrients into milk. Improved feeding can also improve milk composition, hence unit price for milk. If the marginal milk return increases at a faster rate than the marginal cost of production, then cows should be fed at a higher rate.

20.2.7 Diagnosis of poor farm profitability

With regards feeding practices, the causes of poor farm profitability can be diagnosed as follows:

1 Stocking capacity. Is the farm carrying too many stock for the available forage supplies?
2 On-farm forage production. How much of the farm's annual forage supplies must be purchased each year?
3 Forage quality. Is the forage being harvested or purchased at its optimal stage of quality?
4 Concentrate feeding program. What is the quality of the concentrate being fed and how is it being allocated to each cow?
5 Total feed costs. Are the forages and concentrates costing too much per MJ of energy or kg crude protein?
6 Pattern of milk production of the cows. What are their peak milk yields and lactation persistencies?
7 Milk income over feed costs. How do these compare with those of other farmers with good feeding management?
8 Reproductive performance. How many days after calving do cows cycle? What is the herd's 100-day in-calf rate and 200-day not-in-calf rate?
9 Heifer management. What is the calf mortality rate? What is the age and live weight at first calving of the replacement heifers?

Answers to these nine questions should be sought to better understand the farmer's skills in feeding management.

20.2.8 Feeding fewer cows better

Farm development equates to increasing annual farm milk production. Unfortunately too much emphasis has been placed on sourcing more cows to increase herd size, then trying to feed them on the same total feed resources. Rather than purchase more cows, it is always more profitable in the long run, to feed fewer cows better. As cows produce more milk, their maintenance energy requirements (ie the non-profitable component of the feed costs) become more diluted. From Chapter 17 (Tables 17.3, 17.5, 17.7), increasing milk production from 10 to 13 to 17 L/d reduces the maintenance energy component from 51% to 44% to 38% of total energy requirements and increases the proportion of total farm energy converted to milk from 76% to 78% to 81% respectively. Table 17.7 clearly demonstrates that to produce the same annual production of milk, larger herd sizes require rearing more replacement heifers and feeding more dry cows, both non-productive uses of their often limited feed resources.

Nakamanee *et al*. (1999) agree that strategies for increasing milk production per farm should aim at increasing yield per cow rather than increasing herd size. Lack of good quality forage in the dry season is the major problem of most farmers. Appropriate technologies such as improved feed conservation techniques and intensive forage management (eg fertilisation and irrigation) should be transferred to farmers. Farmers need to decrease cost of production in order to compete in the market place.

20.2.9 Breeding versus feeding dairy stock

A major business decision that farmers must make when developing their small holder farms is the emphasis they should place on improving the genetic quality of their milking stock. There is little point in breeding and rearing potentially more productive stock, then underfeeding them following their first calving.

Most Friesian-type cows, purebred and three-quarter bred, are genetically capable of producing at least 20 L, if not 30 L/d of milk at peak production. In most small holder farms, why then do most of them produce no more than 15 L/d at peak? Because they have been underfed, and have not been fed to their genetic potential. The extra herd and feed management skills required to best utilise high genetic merit cows is discussed in Chapter 19.

20.2.10 Growing young stock

In many instances, Friesians imported into South-East Asia may produce well, but their progeny do not. These animals are imported at great expense with expectations that they and their progeny will also outperform local stock. Therefore, farmers are likely to provide sufficient feed for them to produce well while milking. However, unless the feeding management of their progeny is of similar enthusiasm, they will not perform well. As discussed in Chapter 16, smaller heifers are less productive than heavier, better grown heifers. For the progeny of genetically superior cows to also produce well, greater attention needs to be given to their feeding management as young stock.

Chapter 19 has highlighted the more important business decisions farmers should make if they consider that genetic merit is a major limiting factor to their farm productivity and profitability. Greater attention should be given to improving feed supplies to these 'superior' stock both while growing and milking, particularly during early lactation.

20.2.11 Farmer research

The rapid milk response to any changes in feeding management means that dairying is the only form of livestock production that allows farmers to closely monitor animal performance on a day-to-day basis. Every farmer undertakes some form of research whether it is actually measuring daily variations in milk yield with measured changes in the amount of feed offered, or subjectively assessing gross changes in milk output over several weeks with seasonal changes in feed quality.

The future for small holder dairy development will rely on continued research and education of the farmers themselves. Applied research orientated to small holder needs cannot be met solely by importing technologies. Research must acknowledge integrated systems and the role of these farmers while focusing on technical parameters such as feeding, herd recording, management of reproduction and health, milk harvesting and breeding systems. However, its future is often more dependent on national sociopolitical decisions, such as the location of dairying areas in relation to feed resources as well as milk markets, policies on local market protection, compared to free trade from imports. Furthermore, the very perishable nature of the end product, raw milk, when produced in a tropical climate, often with minimal milking hygiene, dramatically influences its end use as fresh, chilled, dried or frozen dairy products.

20.2.12 Demonstration or model farms

To improve adoption of better feeding practices, greater use could be made of model farms. Virtually every day small holder farmers deliver their raw milk to milk collection centres. Such centres, whether run by cooperatives or milk processors, could establish a model farm to extend the principles of good farming practice, such as improved forage agronomy, ration formulation for milking cows, calf and heifer rearing, milking hygiene and other aspects of herd management. Ideally, the model farm should be similar in herd size and forage production area to those in the area from where the milk is sourced.

For example, simple field trials could be set up, such as using fertiliser strips (see Chapter 8) to visually demonstrate yield responses to inorganic fertilisers. Associated data collection and feed analyses could quantify the additional nutrients which could then be followed up with economic analyses to allow farmers to decide for themselves whether to try such practices on their own farms. Similarly, various milking rations could be formulated for comparisons of profit margins, using milk income less feed cost, and to explain the concept of marginal cost of production. With thorough data collection, an entire economic analyses, such as those described in Vietnam (in Chapter 17), could be undertaken to provide guidelines for future policies on rural development in the region. Collaborative studies could be undertaken with government and university dairy researchers, who are usually very short of research facilities, in a more controlled environment than a commercial small holder farm.

Such farms would provide excellent opportunities to evaluate different shed designs and cooling systems, such as those described in Chapter 19. For example, using local materials to construct sheds of various roof heights, insulation materials and internal plans, appraisals could be made of the number of years for such costs to be returned through improved cow milk and reproductive performance.

Not only would these ventures increase the credibility of the milk processors in the area, they could also attract new suppliers to improve their milk quality and daily throughput. Such a venture may even attract additional support from agribusiness, government or even international funding agencies, providing a 'win-win' situation for all those involved in such technology transfer and adoption.

20.2.13 Minimising complexities in feeding management

Not only must farmers work harder to intensify their small holdings, they must also work smarter to comprehend the many new technologies being thrust upon them. Poor adoption rates are often due to the complexities of these new technologies. The policy makers and advisers must fully understand them before they can expect farmers to want to incorporate them into their systems. For example, Multiple Ovulation and Embryo Transfer (MOET) is a technology hardly adopted by western farmers, primarily because the high cost hardly justifies the investment, except possibly for stud farmers who sell pedigree cows, an elite product, rather than raw milk, a bulk commodity. Nevertheless some developing countries (eg China) have taken up MOET, then finding it requires a more sophisticated level of herd and feeding management than exists there.

Many of the 'new' feeding technologies, such as chemically treated rice straw, molasses urea blocks and even silage making, have poor adoption rates because of the extra skills required or the extra time input required. Inorganic fertilisers are also slow to be adopted, presumably because farmers do not believe the extra costs are returned in extra milk. Cassava hay (see Section 20.3) is a new technology but since it requires field curing of the forage to remove the hydrocyanic acid, it requires greater time input. Feeding out formulated concentrates is much simpler than purchasing the raw ingredients and mixing them prior to feeding, even though this practice may save money and allow greater flexibility in supplementary feeding programs.

Generally speaking farmers do not like to double handle forages, just harvest it fresh then feed it directly to their stock. The catchcry with new technology is 'KIS', or 'keep it simple'.

20.2.14 The role for forage legumes

Many benefits are claimed for forage tree legumes. Apart from their value for livestock, they are recognised for their contributions to farming systems, the welfare of rural populations and the protection of the environment (Shelton and Gutteridge 1994). Adoption remains unsatisfactory despite years of promotion. Many reasons have been put forward for the poor levels of uptake, such as lack of understanding of specific needs of farmers and of their socioeconomic environment and mismatches between the environmental goals of development organisations and personal goals of farmers.

There is often inappropriate planting material and support infrastructure provided. Uptake could be advanced, firstly through raising awareness (through workshops and farmer-orientated publications) then secondly, working on-farm where any important social (risks, relevance, labour) and economic (incentives, markets, returns) constraints can be identified and overcome.

There are several examples of successful alley cropping of *Gliricidea* and *Leucaena* on dairy research and farmer training centres in Indonesia, where both fresh and ensiled forages supplement Napier grass. However, to date, there has been little adoption by surrounding small holder dairy farmers.

Forage legumes such as lucerne, berseem or cowpea have a role when undersown into, or sown in rotation with or as a fallow crop, to food crops. They can be exclusive within animal production systems, such as fodder banks and grass legume mixtures, or they can be a component of crop–animal systems providing feeds and improving soil fertility hence food crop yields (Devendra 2001b). Forage legumes also have a role as cover crops in tree plantations, such as oil palm, rubber and coconut, as a means of integrating animals into such systems. Furthermore, they reduce weeds, control erosion and improve soil physical and chemical properties to the benefit of the plantation crop.

As discussed in previous chapters, legumes can significantly improve milk yields and reproductive performance through increases in appetite, digestibility, provision of additional rumen degradable, bypass protein and minerals. These benefits are complemented through reduced feed costs, compared to other protein sources.

20.2.15 An alternative approach to developing feeding systems

The Metabolisable Energy system is considered by many as the most up to date, practical system for describing energy requirements of ruminants, on which to base feeding systems. In most countries, it has replaced the Total Digestible Nutrients (TDN) system for reasons discussed in Chapter 4. In the search for the 'perfect' feeding system, which has been going on for over a century, other systems are being tried and tested.

Researchers working with dairy cows in the humid tropics of Central America have questioned the validity of the Metabolisable Energy system in predicting milk responses to molasses and sugarcane based diets (Preston and Leng 1987). They argue that feeding systems should be based on the principles of:

- maximising rumen function by providing nutrients required by rumen microbes and supplying small amounts of readily digestible fibre
- optimising the balance of nutrients for metabolism through bypass nutrients (eg undegradable dietary protein and bypass starch)
- increasing potential intake of nutrients through improved digestibility
- optimising the balance of minerals through strategic supplementation.

This approach places less emphasis on laboratory and more on actual livestock measurements. In summary, its quantification involves:

- measuring the disappearance of test feeds placed inside small nylon bags that are then inserted inside cows rumens
- feeding small groups of livestock with the test feeds and recording voluntary feed intake

- taking a sample of rumen liqueur and analysing it for ammonia concentration, to assess the adequacy of rumen degradable protein
- feeding livestock with the test feed with and without supplements providing additional undegradable dietary protein to test the adequacy of bypass protein.

Such an approach may not describe the nutritive value of a particular feed or the animals requirements, however it should lead to the development of feeding systems incorporating supplements to ensure more efficient rumen utilisation, hence feed efficiency and/or animal performance.

Quantifying feed intake potential

A similar concern has been expressed by Professor Ørskov of Macaulay Research Institute in Scotland (Ørskov 2002), who considers that current feeding systems may be good for rapidly digested concentrates but do not work well for roughages, particularly those of low quality. A good feed evaluation system should provide farmers with not only an indication of the exchange rate of feeds, but also any feed intake limitations. Developing a measure of intake potential, rather than just feed value (expressed as ME or TDN), would provide a basis on which to match feed potential and animal potential. In other words, it would allow farmers to decide on the most appropriate production systems in different regions to match their feed resources.

Ørskov (2002) uses modern tropical dairying as one example of an unsuitable high potential system. Importing Friesian cows into the humid tropics, where the quality of feed resources often falls far short of enabling these stock to meet their production potential, has all too frequently led to reduced performance (milk and reproduction), poorer disease resistance and their eventual culling from the milking herd. Therefore if the genotype does not match the feeding system, the feeding system should be changed to fit the genotype, in this case by only using better quality feeds for such high genetic merit stock.

Such a feed intake index could indicate whether animals can only consume sufficient for maintenance or additional for production. The index should vary with animal type, such as for buffaloes with their larger rumen volume, and for feeds with specific characteristics, such as anti-nutritional factors limiting appetite. The index could be based on a simple laboratory test such as the rate of gas production when feeds are incubated in a test tube with rumen liqueur. Ørskov's research team (2002) found this measure was closely related to feed intake and growth rate in lambs.

20.3 Cassava–cowpea rotation: An innovative dairy feeding system

Since the 1990s, Professor Metha Wanapat and his team at Khon Kaen University in north-eastern Thailand have been developing dairy feeding systems based on cassava and cowpea hays (Wanapat 1999).

Cassava or tapioca (*Manihot esculenta*) is an annual tuber crop widely grown in tropical regions. It can easily thrive in sandy-loam soils with low organic matter, receiving low rainfall and high temperature. The roots (tubers) are an important cash crop for exporting to livestock feed importing countries, such as Netherlands. A by-product of cassava, their leaves, can be collected from the lower 50% to 60% of the plant, yielding 470 kg fresh/ha or 160 kg DM/ha, without adversely affecting tuber yield. The leaves can be collected every 9 to 10 weeks, allowing two collections during each dry season. About 6 kg fresh (or 2 kg sun dried) leaves can be collected each hour. The leaves are protein rich (up to 25%) with the tannin increasing the proportion that escapes rumen digestion. Cassava leaves do, however, contain high levels of hydrocyanic acid (HCN), a compound toxic to livestock, although sun drying the leaves does reduce hydrocyanic acid levels.

Planting the crop in rows using stems with 30 cm × 30 cm spacing, and harvesting after three months (and then 5 times every 2 mths) by cutting the whole plant at 15 cm above ground yields 11.8 t DM/ha per year. *Leucaena* can also be densely planted in strips (1 m wide and 20 strips /ha) to help fix soil nitrogen. The fresh cassava forage can be left in the field for 1 to 3 days before being collected and made into a 15 kg bale. This bale should be further sun dried to 80% to 90% DM to reduce hydrocyanic acid content and/ or sprinkled with 0.5% urea solution to prevent mould growth.

Professor Wanapat's team found the hay contained 24.9% CP and 44% NDF with a dry matter digestibility of 71%, equivalent to 10.1 MJ of ME/kg DM. Voluntary intake was 3.2% LWT, equivalent to 500 kg cow consuming 16 kg DM/d. Milk thiocyanate levels were increased, which could reduce the rate of milk deterioration by activating lactoperidoxidase (a naturally occurring milk enzyme). The condensed tannin in the cassava leaves was found to increase the populations of rumen bacteria and protozoa (ie enhance rumen ecology) and also reduce the faecal excretion of gastrointestinal nematode eggs. Hence, cassava leaves provide more than just feed nutrients, in that they can improve milk quality, through reducing bacterial contamination post-harvest, and reduce worm infestations (Wanapat 1999).

In two feeding trials, cassava hay replaced concentrates as supplements to cows fed a basal ration of urea-treated rice straw. In the first trial, cows had 0%, 15% and 30% cassava hay in the concentrate mix, fed at the rate of 6 to 8 kg/cow per day. They produced 14.2, 15.7 and 14.9 L/d, respectively, of 3.5% fat corrected milk, with the higher level of cassava hay feeding leading to higher milk fat and protein contents.

In the second trial, cows were fed increasing amounts of cassava hay to partially replace the concentrate mix, producing 12.6 L milk/cow per day on each feeding level; again the highest level of cassava hay feeding produced milk with higher milk fat and protein levels. Therefore, cassava hay can replace some of the concentrate in milking diets without adversely affecting cow performance.

Cassava hay was a more profitable feed as well. With milk returning 11.2 Thai Bt/L, and the concentrate and cassava hay costing 6.0 and 0.5 Bt/kg, respectively, the milk income less feed cost increased from 80 to 116 to 122 Bt/cow per day as cassava hay feeding increased from 0 to 2.8 to 4 kg/cow per day.

Cowpea (*Vigna unguilata*) can be grown as a rotation crop together with the cassava, thus providing additional legume hay to contribute to the home-grown forage base. Cowpea, being a legume crop, will also fix atmospheric nitrogen into the soil, providing as much as 70 to 80 kg N/ha per crop.

These feeding systems have recently been evaluated on 24 farms in North-East Thailand over 60 days in the dry season (Petlum *et al.* 2004). Their results confirmed higher milk yields (13.8 v 12.1 L/cow per day) and higher milk fat contents (3.6% v 3.0%)

when 2 kg/cow per day cassava hay replaced some of the cowpea and *Stylosanthes* hay. On-farm yields of cassava hay averaged 6.8 t DM/ha (Petlum *et al*. 2004) and the level of concentrate fed to the cows was not reported.

20.4 Research priorities in tropical dairy nutrition

20.4.1 An inventory for dairy research in the humid tropics

Chantalakhana (1999) categorised factors limiting farm productivity in the humid tropics into:

- institutional factors, such as dairy cooperatives, suppliers of credit, training, extension services
- government policies, such as development programs, milk promotion, dairy boards
- socioeconomic factors, such as farmer education, off-farm jobs, traditional beliefs
- technical factors, which can be further categorised into feeding, breeding, health
- post-farm gate factors, such as milk processing, marketing and consumption.

He identified the scarcity of good quality forages during the dry or summer season as the most important nutritional problem since most farmers must use whatever is available, sometimes at very high price. Such sources consist of agricultural fibrous residues by-products (eg rice straw, maize stover, soybean stems, pineapple peel, sugarcane tops) and forages or fodder leaves, either produced on-farm or collected from outside the farm.

Further research is required to document the nutritive value of fibrous residues by-products and to develop the logistics to collect, store and feed them in sufficient amounts to provide sufficient supplemental feed for milk production. There is also a need to adapt current hay and silage making systems to small holder operations to conserve forages when required, from one season to another.

A further limiting factor identified by Chantalakhana (1999) was the need to understand the nutrient requirements of, and to develop feeding standards for, tropical dairy cattle. This would allow the formulation of the most suitable and economic rations for small holder cattle in the range of climatic environments encountered in the tropics.

The non-conventional feed source was another area requiring further research into the quality and methods of utilisation. Such feeds include by-products from soybean product factories, oil palm cake and other agro-industrial operations.

Finally Chantalaknana (1999) identified mineral deficiencies adversely affecting milk production and reproduction as key issues, with the need to formulate mineral supplements to prevent deficiencies due to poor quality roughages.

It is one thing researching a problem. If a solution can be found, it is another thing for it to be adopted by the farmers with that problem. The term 'appropriate technology' was developed to describe practical solutions to problems that could be readily accepted, hence undertaken by farmers, particularly traditional ones with minimal resources. Chantalaknana (1999) listed some examples of adoption rate of improved management practices by small holder dairy farmers in Thailand. For nutrition-related technology, there is:

- straw chemical treatment, 0% to 1%
- mineral blocks, 0% to 1%
- pasture, 0% to 1%

- fodder/forage, 11% to 50%
- concentrate supplements (presumably mineral additives), 0% to 1%.

Such poor adoption rates were also highlighted by Shamsuddin *et al.* (2003) who considered throughout South-East Asia that treatment of rice straw with urea was technologically unsuitable for resource-poor farmers while the many attempts to introduce molasses-urea blocks have been unsuccessful in the farmers' communities. Clearly for several reasons, these feeding management innovations should be queried as being 'appropriate technology'.

So why has there been so much research interest and attempted technology transfer over the last two decades in the chemical treatment of rice straw, yet small holder dairy farmers have failed to integrate it into their feeding systems? Might the answer simply be that the small improvement of its nutritive value hardly justifies the effort. Granted, it may have a role in feeding dry cows or young stock, but its potential to improve milk yields must be questioned. It may be a cheaper forage source, but the increased labour input through double handling the straw, into the stack and then into the feed trough, has been a barrier to its adoption.

For interest sake, Chantalakhana (1999) noted the following non-nutrition technologies that have been adopted by more than 1% of farmers:

- crossbreeding, 11% to 50%
- selection, 11% to 50%
- artificial insemination, 1% to 10%
- castration, >50%
- vaccination, 11% to 50%.

Perhaps the most perceptive comment made by Professor Chantalakhana was, 'Science has much to contribute to small holder dairy farming but to do so, researchers must be unusually adept at seeing the world from the farmer's vantage point'.

Figure 20.1 summarises the key priority areas with further research requirements in italics.

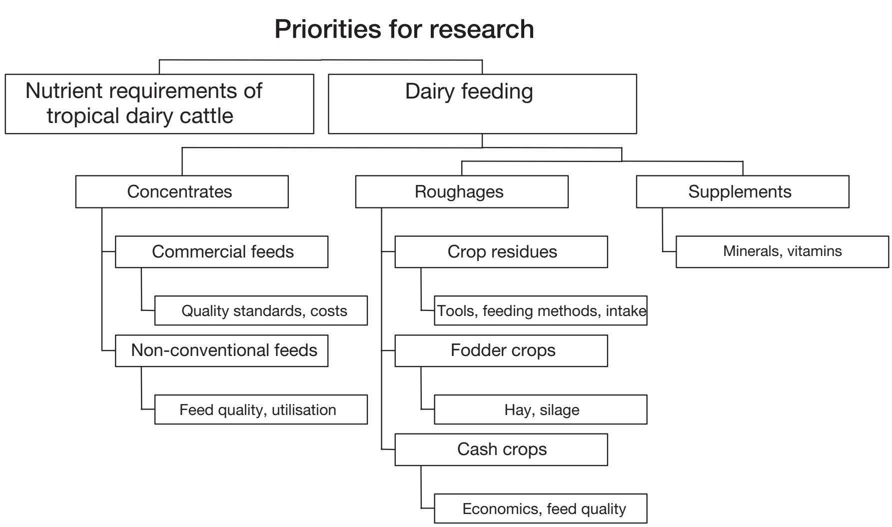


Figure 20.1 A summary of priority research areas in dairy nutrition (Chantalakhana 1999).

20.4.2 The goals for dairy research in the humid tropics

Throughout the world, livestock farmers differ in why they raise and milk dairy stock. Chapters 2 and 3 of this manual discuss many of the many benefits that small holder farmers in the peri-urban and rural areas of the humid tropics derive through dairying. These range from:

- sale of milk, meat and manure
- integration into their cropping systems
- improving the nutritional welfare of their children
- providing employment for their neighbourhood
- providing income for landless farmers
- providing regional industrial development through post-farm gate milk handling and processing
- contributing to social and cultural activities, such as material security and dowries for daughters.

In contrast, dairy farmers from the developed, temperate countries would have income generation from the sale of milk and dairy beef as their major (and often only) objective.

Consequently the goals for dairy research in the humid tropics should also differ to those in temperate countries. With essentially subsistence farmers, such research should be driven towards risk minimisation, whereas in fact most of this research, being conducted by western trained scientists, is directed towards the market orientated dairy systems of free market economies. The objective of much of this research is to increase efficiency and profitability of resource use. Granted this is also relevant to development of the business skills of small holder tropical farmers, but what other goals should tropical dairy specialists have in their research proposals?

Ørskov (2002) has succinctly compared the research strategies and methodologies of these two different research philosophies, as presented in Table 20.3.

Table 20.3 Research goals for market orientated and subsistence dairy production systems
(Source: Ørskov 2002)

Research goals	Market orientated systems	Subsistence systems
Farmer's goal	Profit maximisation Cash generation Productivity	Risk minimisation Family support Stability and sustainability
Scientist role	Design of systems	Management of ecosystem
Intermediate targets	Genetic homogeneity Increased productionpotential Single purpose animals Nutrient mobilisation	Biological diversity Improved maintenancepotential Multi purpose animals Nutrient storage
Philosophical approach	Specific	Holistic
Scientific approach	Single discipline	Multi and trans discipline
Statistical emphasis	Mean Main effects	Variance Interactions

With risk minimisation being the major goal for dairy researchers in the humid tropics, an analysis of risk minimisation has been presented in Table 20.4. The management of risk involves planning for the unexpected that could drastically reduce the farm's profitability, hence its long-term viability or at worst, decimate the farm (eg an outbreak of virulent disease or zero reproductive performance). Table 20.4 presents the likelihood of various risks impacting on the farm, the ability of the farmer to address the problem, the strategy to rectify it and the chapter in this manual in which this is discussed.

Table 20.4 Analyses of risk minimisation for tropical small holder dairy farmers
The last column lists the Chapter (Chap) in this manual in which the risk is discussed.

Ease of influencing	Risk	Likelihood of occurrence	Strategy to rectify risk	Chap
Difficult	Adverse climate	High	Cannot be overcome	–
Outside farmer control	Poor industry infrastructure	Moderate	Government policy and investment	2, 3
	Uncertain industry future in region	?	Government policy	–
	Poor industry technical support	Moderate	Government training programs	1
Probable	Inappropriate breed	Moderate	Government support	19
Farmer has some influence	Low base milk price	Moderate	Government, agribusiness & cooperative negotiations	17
	Poor dairy genetic merit	Moderate	Government importation programs	19
	Low post-farm gate milk quality	Moderate	Cooperative infrastructure	17
Possible	Low farm income	Moderate	Feeding and herd management	17
Farmer has great influence	Inadequate water	Moderate	Farm development	6
	Poor forage quality	High	Agronomic practices	8
	Low forage availability	High	Farm development	8
	Poor concentrate quality	Moderate	Cooperative program	11
	Low concentrate feeding	Moderate	Feeding management	11
	Adverse diseases	Moderate	Herd management & cooperative programs	13
	Low farm milk price	Moderate	Feeding management	17
	Poor milk composition	Moderate	Improved feeding	14
	Poor on-farm milk quality	Moderate	Improved hygiene	17
	Inefficient effluent system	Moderate	Facilities and herd management	19
	Adverse heat stress	High	Shed design and herd management	19
	Poor reproductive performance	Moderate	Herd management	15
	High cost of production	Moderate	Farmer management skills	17
	Poor young stock performance	Moderate	Feeding management	16
	Low farm profitability	Moderate	Farm and herd management	17
	Increased farm investments	Moderate	Cooperative advice	–

Most of the on-farm risks over which farmers have great influence have a moderate to high likelihood of occurring and also have some nutritional basis. Many of the actions to rectify each problem are discussed in this manual, although some not in great detail.

With regards modifying herd and farm management to minimise risk, some of the actions not specifically discussed in this manual include:

- minimising the number of milking cows that are non pregnant and not lactating as these animals will not contribute to farm incomes for many months
- ensuring sufficient replacement heifers are reared, at least 20% of the milking herd
- initiating simple recording systems for the most useful economic measures such as daily milk yields per cow, when cows calved and showed heats, veterinary and medicine treatments of sick stock
- developing an annual feed budget (for both forages and concentrates) and plan to purchase feeds well in advance of when they are needed
- prioritising farm investment, for example, develop forage production areas and sheds before purchasing 'superior', higher genetic merit stock
- concentrating efforts on low cost management practices that return the most in milk income, such as providing hot water for washing and sterilising milk handling equipment
- becoming an active member of farmer cooperatives, since their farm management and profits can greatly benefit through more effective services
- becoming an information seeker, both male and female farming partners, and making full use of what sources of technical information are provided by government, cooperatives and agribusiness – many of them are free
- investing in farm infrastructure requires professional support, which should be sought via cooperative management
- farmers being forced to increase farm outputs, due to farm costs increasing and the likelihood of milk returns not increasing; hence farmers must intensify their production systems just to remain viable.

20.5 Improving current dairy feeding systems in the humid tropics

To improve current feeding management, it should be viewed in a farming system perspective (Devendra 2001a). The following prerequisites are important:

- knowledge of the availability of the totality of feeds (forages, crop residues, agro-industrial by-products, non-conventional feed resources) throughout the year
- synchronise their availability with herd requirements
- assess the extent to surpluses and feed deficits
- develop strategies to cope with the shortfalls
- increase feed production, such as multipurpose tree legumes and development of food-feed systems
- justify purchasing concentrates, either as ingredients or already formulated, and prioritise their use with different types of dairy stock and at different times of the year
- develop feed conservation measures to reduce seasonal variability in on farm forage supplies
- strategically supplement for milk production, especially during dry seasons.

These prerequisites need to be considered in holistic terms to maximise efficiencies of feed resource use. In the absence of such a holistic focus, research and development concerning feed resource use will continue to be a piecemeal approach, mainly component technology intervention with variable success (see also Table 20.3).

Ruminant production systems are unlikely to change in the foreseeable future. New proposed systems and returns from them would therefore have to be demonstrably superior and supported by massive capital input and other resources. However, Devendra (2001a) considers that there will be increasing and predictable intensification and a shift within production systems. This is increasingly likely with decreasing availability of arable land. The major objective for improved feeding and nutrition should then be to maximise the use of available feed resources, such as crop residues and low quality roughages. Unfortunately their potential to intensify small holder dairy systems is limited.

During the recent Asian economic crisis, the small holder dairy farms that collapsed were those dependent on imported feeds, notably maize and supplements. Good profits still accrued from systems based on indigenous feeds. Therefore, approaches to promote and maximum their use and self-reliance are essential for the long-term viability of small holder livestock farming.

Unfortunately much of the improvements in small holder dairy production through crossbreeding and interventions with nutrition and health have been supply driven, without farmer participation, and on government experiment stations. Many of these have been seldom adopted, mainly because there was a lack of farming systems perspective. This has led to incomplete awareness, hence consideration, of the important interactions between nutrition, genotype and disease. In addition the interactions between animals and crop production have been underinvestigated, given that most dairy animals are found on mixed farms (Devendra 2001a).

Much of current small holder dairying is found in irrigated areas, where land is already overused. Opportunities exist for expansion into rain-fed lowland areas where soil moisture, hence crop production, is relatively high. Within Asia, 82% of the available land is rain-fed with much of that in subhumid zones, where over 50% of the large and small ruminant animals are located. Poverty is all too common in these areas while natural resource degradation is intense.

The close link between small holder dairying and urban development, resulting from community awareness of the nutritional and health benefits of dairy products, should benefit resource-poor farmers. Of all the livestock industries, dairying has the largest 'multipier effect' in that every dollar generated on farm from milk production generates more dollars post-farm gate than for meat, fibre and egg production. The income generated by such farmers provides many employment opportunities, hence additional income:

- post-farm gate through the handling, storage and processing of raw milk then
- post processing plant through cooperative and government support and the frequent distribution of dairy products to consumers.

The role of dairy cattle in integrated farming systems is often overlooked by dairy specialists. Small holders may not consider becoming primarily dairy producers until they find an assured market yielding a reliable income. Many still prefer to integrate their dairy enterprise with other farming activities. This creates efficiencies in family labour usage, use of residues and farm recycling. Small holders should then view their dairy cows as fertiliser producers, potential power supply for cultivation, companions, users of easily grown or procured fodder, a self-replacing crop, saleable assets from time to time, an acceptable livestock enterprise, and various other modes (Devendra 1999). Such an integrated approach then creates a complex enterprise requiring a better understanding of the interactions with other socioeconomic aspects of small holder farming.

There is no other system of tropical agriculture that allows virtually landless farmers the opportunity to generate a substantial daily income through harvesting wasted forage from the roadside, rice paddies or plantations, particularly there is government support through credit schemes for supplying livestock. Their integration into dairy cooperatives provides further services, such as veterinary, artificial insemination and formulated concentrates, and can guarantee good farmer returns. Nutrient transfer via cow manure improves crop yields while integrated management of natural resources ensures a more sustainable industry.

The major limiting factor when feeding dairy cows on small holder farms in the humid tropics is, and will be for many years, the supply, intake and utilisation for dietary energy. Unfortunately there is no such thing a 'magic bullet' with regards improving milk responses or feed efficiency, meaning that there are no short cuts to improving the feeding management of dairy cows. Production response to such feed additives (specific vitamins or minerals), rumen modifiers or other single action supplements depend largely on the nutritional well being of the rumen microflora, the blood metabolites and the mammary gland. These are largely influenced by the major feed nutrients – water, energy, protein and fibre – in that order.

Basically improving the profitability of small holder dairying, as quantified by milk income less feeding costs, can only be achieved through following the basic principles described in this manual. Such improvements are incremental, depending on current feeding management skills.

In the dairy industries of most Western countries, environmental sustainability is becoming a major concern of legislators, government and practitioners in research, development and extension. This has yet to happen in the humid tropics and hopefully it will also occur and in the not too-distant future. But to quote a new catchcry, 'it is hard to be green when you are in the red'. Such an excuse is likely to delay these concerns in South-East Asia.

20.6 Future directions for small holder dairy production in the humid tropics

The following are some of the key issues in feeding management that require further attention at both the research and extension levels (Moran 2004):

Feed nutrients

- As forage supplies are of paramount importance, cost effective, year-round and sustainable supplies of quality roughages must be developed for every system of small holder dairy farming.

- Because dry season forages are poorer in nutritive value, conserved excess wet season forages often form the basis of most profitable dairy systems.
- Tropical forages are high in fibre, so farmers will always require concentrate supplements.
- Energy will continue to be the major limiting feed nutrient in small holder dairying. Improving the energy status of milking cows will be of benefit to both the production of milk and milk solids and a regular supply of calves.
- Home-grown forages will almost always be cheaper sources of feed nutrients than purchased forages, particularly when managed to provide optimum yields and quality.

Feeding management

- The high nutrient demands of milking cows negates many of the recommended feeding systems based on chemically treated low quality roughages.
- Agro-industrial by-products will always form the basis of concentrate supplements, because of increasing demand for land to grow crops for human consumption.
- With continuing emphasis on increasing the domestic milk production in all South-East Asian countries, it is important not to 'overstock' any developing dairy region. Feed audits, particularly of 'home-grown' forage supplies, should be undertaken and adhered to when projecting optimum numbers of dairy stock for any particular region.
- In addition to encouraging farmers to improve agronomic practices on their own small holder farms, 'home-grown' forages can be produced on communal areas, utilising the expertise of cooperative staff to oversee management to optimise fertilising, harvesting and, if necessary, conservation of quality forages for use by nearby farmers. If there are economic justification for cooperatives to bulk purchase ingredients and formulate concentrates, similar benefits could arise with managing forage production areas.
- High yielding cows are very susceptible to heat stress. Every effort should be made to alleviate the adverse effects of heat stress on appetite, fertility, hence milk production and profitability.
- An underutilised measure of feeding management is the persistency of the lactation curve. It is one thing to feed for high peak yields, but it is just as important for good milk yields to be maintained throughout the lactation. Farmers should feed cows to allow milk yields to fall by no more than 10% from peak yield per month.

Other issues

- There is little sense in importing 'improved genetics' or growing out bigger heifers if they cannot be fed well when milking.
- Dairying is a business, so feeding decisions should be based on logical and appropriate economic information with 'milk income above feed costs' being the single most useful measure of success.
- Improving the knowledge of basic ruminant nutrition will greatly assist many dairy advisers to formulate more profitable milking rations, because generic recipes are notoriously unreliable.

- Farm development is often limited by inefficient (and even inappropriate) technology transfer, in that extension procedures do not always acknowledge farmer skills and adult learning principles.

Concern is often expressed that most countries in South-East Asia are not in a position to develop large scale intensive livestock industries without the importation of feed stuffs. This certainly applies to pig and poultry but for dairying, another relatively intensive industry, the future is not for large farms requiring high tonnages of fresh forages and imported concentrates. Unlike Europe, North America and Australasia, where dairying evolved from small holders to larger and often corporate farms, I believe the future for dairying in South-East Asia is with the small holder sector. For these systems, fresh quality forages can be sourced close by while local by-products will form the bulk of concentrates.

Even in one of the most densely populated island in the world, Java, there are large tracts of underutilised land such as forest plantations and aging coffee and rubber plantations, where small holder dairy farmers can freely harvest limited amounts of forage for their stock. In recognising their potential, Indonesian policy makers place high priority in developing such resources through providing greater access to farmers and plantings of improved forage species (Burrell and Moran 2004). With better feeding management skills, small holder farmers can profitably increase raw milk supplies, to the nutritional benefits of their fellow consumers and the improved food security of their nations.

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Glossary and abbreviations

Terms in this glossary are defined in the context of their use in this manual.

A

acetate or acetic acid. A product of rumen digestion, produced in the main by cellulose-digesting bacteria; important in the production of milk fat.
acid detergent fibre or ADF. The less digestible or indigestible parts of the fibre; ie the cellulose and lignin only.
acidosis. An excessive increase in rumen acid caused by feeding too much grain or other starchy feeds or by introducing them into the diet too quickly.
ad libitum. Fed to appetite
Animal Production Level (APL). A measure of the level of performance of a cow calculated as the energy requirements expressed as a proportion of maintenance energy requirements.
amino acid. The building block of proteins; a cow requires 25 different amino acids for normal metabolic functioning.
appropriate technology. A term developed to describe practical solutions to problems that could be readily accepted hence undertaken by farmers, particularly traditional ones with minimal resources.
as-fed . Feed with its moisture still in it.
associative effects. Changes in utilisation of one feed type following supplementation with a second feed type, such as decreasing digestibility in forages with increasing supplementation with concentrates. This means that assuming additive effects of supplements can overestimate milk responses.
Australian Friesian Sahiwal (AFS). A tropically adapted dairy breed developed in Australia based on Friesian and Sahiwal.
Australian Milking Zebu (AMZ). A tropically adapted dairy breed developed in Australia based on Jersey and Red Sindhi.

B

body condition. Energy stored in body reserves by cows, predominantly as fat.
buffer. Body fluid (eg., saliva) or feed additive that reduces the acidity in the rumen.
butyrate or butyric acid. A product of rumen digestion of lesser importance in milk production than acetate and propionate.
bypass protein. See undegradable dietary protein.

C

°C. Degrees Celsius.
Ca. Calcium.
carbohydrates. The main source of energy in a cow's diet.
carnivore. Meat eater.
casein. Milk protein.

cellulose-digesting bacteria. Type of rumen microbe that can be eliminated or severely slowed in growth rate by high-fat diets or high acidity in the rumen.
Cl. Chloride.
cm. centimetre.
Co. Cobalt.
colony farming. A term used in Indonesia to describe a system of dairy farming where many small holders house their stock in large sheds but still maintain independent feeding and herd management.
conception rate. The proportion of the total number of services or inseminations that result in pregnancy.
condition score. Objective visual assessment of a cow's body condition on a scale of 1 (emaciated) to 8 (obese).
correction factor. A factor used to adjust the total energy requirements for the level of cow performance, using the Animal Production Level.
crude fibre (CF). A measure of fibre in the diet now considered unacceptable as it does not always take into account all of the constituents that make up the fibre component of a feed; it measures only the alkali-soluble lignin and the cellulose.
crude protein (CP). A rough measure of all the protein in the diet (NPN + RDP + UDP); it assumes (incorrectly) that all the nitrogen in a feed comes from protein.
Cu. Copper.

D
d. day.
DDM. Digestible dry matter.
DE. Digestible energy.
digestibility. The proportion of the dry matter in a feed that gets digested; it is the difference between what is eaten and what comes out as manure.
digestible energy. Energy that is actually absorbed by the cow.
dry matter or DM. The proportion of any feed remaining after all the water has been taken out.

E
energy. The part of a feed that is used as 'fuel' in carrying out the cow's bodily functions.
energy-dense. Having a large amount of metabolisable energy per kilogram of dry matter.
enzyme. A substance produced by the cow that helps digestion.
eructation. The belching of gases produced in the rumen during carbohydrate fermentation.
essential amino acid. Any of the 10 amino acids that the cow cannot make herself and therefore must be supplied from the diet or from the products of digestion.

F
Food and Agriculture Organization of the United Nations (FAO). The organisation within the United Nations structure that documents agricultural statistics and facilitates development in agriculture, particularly in the poorer countries of the world.
Fe. Iron.

fibre. The cell wall, or structural material, in a plant made up of (among other things) cellulose, hemicellulose and lignin.

G

g. gram(s).
g/d. gram(s) per day.
g/L. gram(s) per litre.
Good Agricultural Practices (GAP). Recommended farming practices to minimise problems of on-farm contamination of livestock products which reduce consumer safety.

H

hemicellulose. The most digestible part of fibre; included in NDF analyses but not in ADF or CF analyses.
herbivore. Plant eater.
hormone. A chemical produced by the cow that regulates body functions.

I

I. Iodine.
international units (IU). The unit of measure used for vitamins.

J

joule. A unit of energy; one calorie equals a bit more than 4,000 joules.

K

K. Potassium.
kg. kilogram(s).
kg DM. kilogram(s) of dry matter.
km. kilometre(s).

L

L. litre(s).
L/d. litre(s) per day.
lead feeding. Gradual introduction of cereal grain to cows just before calving
lignin. An indigestible part of plant fibre.
live weight (LWT). Weight of live cow, measured in kilograms.
LWG. Live weight gain.
local currency units (LCU). Units of currency used in different countries (see Appendix 3).

M

maintenance requirement. The energy needed for essential body functions, such as blood circulation, breathing, keeping warm or cool, digestion, and tissue repair.
marginal. The change in output per unit change in input, for example, marginal milk response is the change in milk yield per kg DM intake, for the next kg DM consumed
mastication. chewing.
metabolic activities. For an adult cow, maintenance, milk production, activity, pregnancy, and weight gain; for an immature cow, also growth.

metabolisable energy (ME). The amount of energy provided by a feed after deducting energy lost to faeces, urine, heat and gas production; it is the energy available to be used by the cow for her metabolic activities. *See also* digestible energy.
metabolism. A general term for all chemical activities of living organisms; it includes respiration, fermentation, and repair of body tissues. *See also* metabolic activities.
Mg. Magnesium.
mg. milligram(s).
mg/kg. milligram(s) per kilogram.
mg/kg DM. milligram(s) per kilogram of dry matter.
microbes. Microorganisms that live in the rumen and digest dietary forages
Milk income less feed costs (MIFC). A measure of profitability calculated from the income from milk sales less the total cost of feed inputs
MJ. megajoule(s), millions of joules.
MJ ME/kg DM. megajoules of metabolisable energy per kilogram of dry matter.
mm. millimetre.
Mn. Manganese.
Mo. Molybdenum.
Multiple ovulation and embryo transfer (MOET). A reproductive management practice to increase the number of calves produced from high genetic merit dairy cows.

N

N. Nitrogen.
Na. Sodium.
neutral detergent fibre (NDF). A measure of all the fibre (hemicellulose, lignin, cellulose) in a feed; it indicates how bulky the feed is.
NH_3. Ammonia.
non-protein nitrogen (NPN). Not actually protein but simple nitrogen; however, microbes can make protein from simple nitrogen if enough energy (carbohydrate) is available in the rumen at the same time.

P

P. Phosphorus.
partitioning. The metabolic division of energy intake (above the maintenance requirement) between live weight gain and milk production.
per. In each or for each.
per cent. In or for each one hundred; for example, 5% means 5 in (or for) each 100: if the interest rate on a loan is 5% per year, you pay $5 a year for each $100 not yet repaid, or if the dry matter per kilogram is 5%, then 50 grams in each kilogram (1,000 grams) is dry matter.
percentage. The rate or proportion per hundred.
peri-urban farms. Farms located on the outskirts of large towns and cities, benefiting from close proximity to consumers hence markets, as well as being able to easily source forages in nearby rural areas and agro-industrial by-products from urban food processors.

pH. A measure of acidity or alkalinity on a scale from 1 (extremely acid) to 14 (extremely alkaline).
ppm. parts per million; equivalent to milligrams per kilogram.
probiotics. Compounds and micro-organisms that improve feed digestion and utilisation.
propionate or propionic acid. A product of rumen digestion, produced in the main by starch-digesting and glucose-digesting bacteria; important in milk volume and milk protein production. *See also* propionic acid.
protein. The material that makes up most of the cow's body (muscles, skin, organs, blood); it also is part of milk.

Q

quality. In relation to feeds, it is an indication of the level of energy and digestibility. In relation to milk, it refers to the level of various contaminants in milk, such as bacterial, chemical or any other adulterations that can be detected.

R

R, D and E. An abbreviation for research, development and extension.
rumen degradable protein (RDP). The portion of protein in the diet that is digested and used by the microbes in the rumen to build themselves, if enough energy (carbohydrate) is available at the same time.
rumen modifier. A product that changes the rumen conditions and/or microbes and thereby changes the fermentation process and the products of fermentation.
rumen undegradable protein. See undegradable dietary protein.
rumination. Regurgitation and chewing of the cud.

S

S. Sulfur.
Se. Selenium.
soluble carbohydrates. Include the sugars and simple carbohydrates, which are quickly dissolved and digested in the rumen, produce mainly propionate, are non-fibrous, and are found within the plant cell.
Solids-not-fat (SNF). An alternative measure of milk composition to milk protein. SNF contains milk protein, lactose and minerals, allowing milk protein percentage to be calculated as (SNF% [–] 5.4).
South-East Asia (SE Asia). The countries in this region of Asia, namely Cambodia, Indonesia, Laos, Malaysia, Myanmar (or Burma), Philippines, Thailand and Vietnam.
storage carbohydrates. Include starch, are quickly dissolved and digested in the rumen, produce mainly acetate, are non-fibrous, and are found within the plant cell.
structural carbohydrates. Include lignin, hemicellulose, and cellulose; are dissolved and digested slowly (if at all) in the rumen; are fibrous; and are found in the cell wall.
submission rate. The proportion of the herd inseminated at least once in a given period of time (eg the first 10, 21, 24 or 30 days of mating).
substitution. The extent to which a supplement replaces forage in the diet.
supplement. A feed or product added to the cow's diet to increase the intake of some dietary component, such as energy, protein, fibre, vitamins or minerals.

T

Temperature Humidity Index (THI). A system for quantifying heat stress based on temperature and humidity. The higher the index, the greater the discomfort, and this occurs at lower temperatures for higher humidities.

Total Digestible Nutrients (TDN). A system of describing dietary energy based on proximate analyses (ash, nitrogen, ether extract, crude fibre). Formula uses crude protein, crude fibre, ether extract and nitrogen-free extract.

Total Plate Count (TPC). A measure of bacterial contamination of raw milk in millions of bacterial colony forming units per milllitre of milk.

Total Solids (TS). A measure of milk composition expressed in percentage of total milk solids (milk fat, milk protein, lactose, minerals).

transition period. The five-week period between three weeks prior to and two weeks after calving when feeding management can have a large influence on cow health and productivity in early lactation.

U

undegradable dietary protein (UDP). Any protein in the diet that passes through the rumen without breaking down and is digested in the abomasum and small intestine. Also bypass protein.

ultraviolet light (UV). Radiation from the sun which can rapidly deteriorate silage plastic.

V

volatile fatty acids (VFA). The general term for the products of rumen fermentation; the most important of these acids are acetic, propionic and butyric acids, which are major energy sources for the cow.

Z

Zn. Zinc.

Appendix 1 Temperature Humidity Index

The following table presents the Temperature Humidity Index (THI), calculated from temperature (in degrees Farenheit or Centigrade) and relative humidity (%), highlighting its effect on cow stress and hence performance.

Temperature		Relative humidity																				
Deg F	Deg C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.2																				72	72
73	22.8																		72	72	73	73
74	23.3																72	72	73	73	74	74
75	23.9														72	72	73	73	74	74	75	75
76	24.4												72	72	73	73	74	74	75	75	76	76
77	25.0											72	72	73	73	74	74	75	75	76	76	77
78	25.6										72	73	73	74	74	75	75	76	76	77	77	77
79	26.1									72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.7							72	72	73	73	74	74	75	76	76	77	78	78	79	79	80
81	27.2						72	72	73	73	74	[illegible]	75	76	77	77	78	78	79	80	80	81
82	27.8						72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.3					72	73	73	74	74	75	76	77	78	78	79	80	80	81	82	82	83
84	28.9				72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.4			72	72	73	74	75	75	76	77	78	79	79	80	81	81	82	83	84	84	85
86	30.0			72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.6		72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	86	85	85	86	87
88	31.1	72	72	73	74	75	75	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.7	72	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	89
90	32.2	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	32.8	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.3	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	33.9	74	75	76	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91	92	93
94	34.4	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.6	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.1	76	76	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.7	76	77	78	79	80	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97	98
99	37.2	76	77	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	96	97	98	99
100	37.3	77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	
101	38.3	77	79	80	81	82	83	86	86	87	88	89	90	92	93	96	95	96	97	99		
102	38.9	78	79	80	81	83	86	85	86	87	89	90	91	92	96	95	96	97	96			
103	39.6	78	79	81	82	83	86	86	87	88	89	91	92	94	95	96	97					
104	40.0	79	80	81	82	86	85	86	88	88	90	91	93	94	95	96						
105	40.6	79	80	82	83	86	86	87	88	89	91	92	93	96	96	97						
106	41.1	80	81	82	86	85	86	88	89	90	91	93	94	95	97	98						
107	41.7	80	81	83	86	85	87	88	89	91	92	94	95	96	98							
108	42.2	81	82	83	85	86	87	89	90	92	93	94	96	97								
109	42.3	81	82	86	85	87	88	89	91	92	94	95	96	98								
110	43.3	81	83	86	86	87	88	90	91	92	94	96	97									
111	43.9	82	83	85	86	88	89	91	93	94	95	96	98									
112	44.4	82	86	85	87	88	90	91	94	94	96	97										
113	45.0	83	86	86	87	89	90	92	95	95	96	96										
114	45.4	83	85	86	88	89	91	92	94	96	97											
115	46.1	86	85	87	88	90	91	94	95	96	98											
116	46.7	86	86	87	89	90	92	94	95	97												
117	47.2	85	86	88	89	91	93	94	96	98												
118	47.3	85	87	88	90	92	93	95	97													
119	48.3	85	87	89	90	92	94	96	97													
120	48.9	86	88	89	91	93	94	96	98													
121	49.4	86	88	90	92	93	95	97														

A

B

C

E

Five comfort zones for milking cows

A	<72	No stress
B	72–78	Mild stress
C	78–89	Severe stress
D	89–98	Very severe stress
E	>98	Dead cows

Source: Dr Frank Wiersama (pers. comm. 1990). Dep Agric. Eng., University of Arizona, Tuscon, Arizona, USA

Appendix 2 Conversion of units of measurements

1 Abbreviations

ac	acre	yr	year
mm	millimetre	mg	milligram
cm	centimetre	kg	kilogram
m	metre	g	gram
mL	millilitre	J	joules
ppm	parts per million	L	litre
K	kilo or thousands	lb	pound
M	mega or millions	ft	foot
MCal	megacalories	hd	head
MJ	megajoule	sq	square
MT	megatonnes	$	dollar
min	minute	c	cent
ha	hectare	<	less than
hr	hour	>	greater than
d	day		

2 Conversion of Imperial units to metric units

Length:	1 inch = 25.4 mm
	1 foot = 30.5 cm
	1 yard = 0.91 m
	1 mile = 1.61 km
Volume:	1 cu ft = 0.028 m^3
	1 pint = 0.57 L
	1 gallon = 4.54 L
	1 bushell = 36.4 L
	1 acre foot = 1.23 ML (megalitre)
Area:	1 acre = 0.40 ha
	1 sq mile = 2.59 km^2
Weight:	1 ounce = 28.3 g
	1 pound = 0.454 kg
	1 hundred weight = 50.8 kg
	1 long ton = 1017 kg (2240 lb)
Energy:	1 calorie = 4.19 joules
Density:	1 lb/ft^3 = 0.063 kg/m^3
Rate:	1 gallon/acre = 11.23 L/ha
	1 pound/acre = 1.12 kg/ha
	1 gallon/ton = 4.17 L/t
Pressure:	1 pound/sq in (psi) = 1.45 kPa (kilopascals)
Yield:	1 lb/ac = 1.12 kg/ha

Temperature:	1°F = ((9/5) * C) + 32
	1°F = 0.56°C
	50°F = 10.0°C
	60°F = 15.6°C
	70°F = 21.1°C
	80°F = 26.7°C
	90°F = 32.2°C
	100°F = 37.8°C
	110°F = 43.3°C

3 Conversion of US units to metric units

Volume:	1 gallon = 3.79 L
	1 bushell = 35.2 L
Weight:	1 hundred weight = 45.4 kg
	1 short ton = 907 kg (2000 lb)
Milk prices:	$10/hundred weight = 22.0 c/L
	Forage maize yields @ 30% DM:
	25 ton fresh weight/acre = 16.8 t DM/ha
Food energy:	1 % unit TDN = 0.185 MJ/kg DM of metabolisable energy
	30% TDN = 3.7 MJ/kg DM of ME
	40% TDN = 5.5 MJ/kg DM of ME
	50% TDN= 6.4 MJ/kg DM of ME
	60% TDN= 7.4 MJ/kg DM of ME
	70% TDN= 8.3 MJ/kg DM of ME
	80% TDN= 9.2 MJ/kg DM of ME
	1 MCal/lb = 9.22 MJ/kg
	1 MCal/kg = 4.19 MJ/kg

4 Conversion of other specific country units to metric units

Most countries now use the metric units of measure; however certain countries have their own historical units, which are still used by farmers and advisers.

China

Length:	1 chi = 33 cm
	1 li = 500 m
Volume:	1 gongsheng = 1 L
Weight:	1 jin = 500 g

Thailand

Length:	1 nui = 2.1 cm
	1 kheup = 25 cm
	1 sawk = 50 cm
	1 waa = 2 m
	1 sen = 40 cm
	1 yoht = 16 km
Weight:	1 baht = 15 g
	1 tamleung = 60 g
	1 chang = 1.2 kg
	1 haap = 60 kg
Area:	1 sq waa = 4 m^2
	1 ngaan = 400 m^2
	1 rai = 1.6 ha

Appendix 3 Currency converter for South-East Asia

Rather than express costs and returns in one currency (conventionally $US dollars), this manual makes use of currencies from various South-East Asian countries. For the reader's benefit, rather than convert them all to a single currency in the text, the following currency converter compares their relative values in February 2005. More up to date conversions can be obtained via the internet from a currency converter located at http://www.xe.com/ucc.

Relative values of selected currencies in February 2005

Country	Currency unit	000 Rp	1 MR	1 Ps	1 Bt	000 VND	1 A$	1 US$	1 RMB
Indonesia	Rupiah (Rp) x 1000	–	2.42	0.17	0.24	0.58	7.09	9.21	1.11
Malaysia	Ringgit (MR)	0.41	–	0.07	0.10	0.24	2.92	3.80	0.45
Philippines	Peso (Ps)	5.94	14.4	–	1.42	3.47	42.2	54.7	0.61
Thailand	Baht (Bt)	4.18	10.1	0.70	–	2.44	29.7	39.5	4.66
Vietnam	Dong (VND) x 1000	1.72	4.2	0.28	0.41	–	12.1	15.8	0.12
Australia	A$	0.14	0.34	0.02	0.04	0.08	–	1.30	0.16
United States	US$	0.11	0.26	0.02	0.03	0.06	0.77	–	0.12
China	Rendimbi (RMB)	8.99	2.18	0.15	0.21	0.52	6.37	8.28	–

Appendix 4 Vitamins and minerals required by dairy cows

Vitamins required by dairy cows

Vitamin A

Vitamin A (retinol) is a component of the visual pigments in the eye. It is also involved in the formation of tissue and bone and is required for growth, milk production and reproduction. Excess vitamin A is stored in the liver for up to three to four months.

Vitamin A is formed from dietary carotene in the intestinal wall. Most of the vitamin A requirement is met by the consumption of grasses. Deficiencies of vitamin A are uncommon in forage-fed cattle but can occur in cattle fed diets high in cereals or cereal straws or in calves fed low fat milk replacers low in vitamin A.

Vitamin D

Vitamin D is closely involved with calcium (Ca) and phosphorus (P) metabolism as it is required for Ca and P absorption and deposition within bone. It also stimulates the absorption of calcium from the small intestine. If Ca and P levels are adequate in the diet, the need for vitamin D is small.

Vitamin D is also required for the growth and maintenance of teeth and bone. Vitamin D is used in the prevention of milk fever. However, the effectiveness of vitamin D in treating milk fever is reduced when dietary calcium is too low or too high. The best results are achieved when calcium intakes are in the order of 50 to 70 g calcium/d.

Vitamin D is formed in the skin following exposure to sunlight and is stored in the liver. Deficiencies are rare; however, vitamin D toxicity has been observed in cows given excessive doses of vitamin D during the treatment of milk fever. Vitamin D toxicity results in the calcification of the body's soft tissues (especially the aorta in the heart).

Vitamin E/Selenium

A deficiency of either vitamin E or selenium (Se) leads to muscular dystrophy (white muscle disease) which produces stiffness, uncoordinated movement and in severe cases, death from heart failure. Vitamin E prevents damage to cell membranes.

Both vitamin E and Se have anti-oxidant properties that protect biological systems from degradation and may be important in maintaining reproductive health. Research has found that Se accumulates in body tissues important to reproductive health. There is some suggestion that Se deficiency may cause early embryonic loss. Animals deficient in Se and vitamin E may have suppressed defences against infectious diseases.

Cows supplemented with vitamin E and Se have demonstrated improved conception rate, sperm transport, increased uterine contractions moving towards the oviduct, more robust immune systems (leading to reduced incidence of metritis) and reduced cases of retained foetal membranes and cystic ovaries.

Selenium and vitamin E supplementation is of value in areas deficient in Se when such deficiencies are limiting reproductive performance.

Minerals required by dairy cows

1. Macrominerals

Mineral	Interfering factors	Function	Major sources	Notes
Calcium (Ca)	Phosphorus, vitamin D	Component of bone and teeth, involved in heart, muscle and nerve function and blood coagulation. Essential for milk production	Bone reserves mobilised during mild dietary deficiencies, legumes, grasses	Absorbed from rumen and small intestine at a rate equivalent to the rate needed, regardless of intake. Concentration in milk is constant – milk production is the main variable affecting requirement
Magnesium (Mg)	Potassium, high levels of rumen ammonia	Nerve and muscle function, carbohydrate and lipid metabolism, involved in the secretion of some hormones. Has a role in regulating calcium in blood and bone	Legumes, grasses, causmag, Epsom salts or magnesium chloride	Absorbed in rumen and stored in bone. Bone reserves inadequate to meet daily requirements. Excess Mg excreted in the urine. Excess Mg (greater than 60g/d) causes diarrhoea in cattle and inhibits absorption of calcium and phosphorus
Phosphorus (P)	Calcium, vitamin D, phytic acid	Needed for sound bone and teeth. Vital component in protein, buffer in saliva	Legumes, grasses, bone flour, Di Ammonium Phosphate, monosodium phosphate	Absorbed from the small intestine, also found in bone. Excess P recycled in saliva. P relies on mechanism which mobilises calcium from bone. Excess P interferes with absorption of calcium
Potassium (K)		Essential for enzyme, muscle and nerve function. Major role in carbohydrate metabolism and in nerves and muscles	Grasses, potassium chloride	Absorbed in intestine, excess K excreted in urine. Excess K reduces absorption of magnesium from rumen, especially when sodium is low
Sodium (Na) Chlorine (Cl)		Na necessary for absorption of sugar and amino acids from the digestive tract. Cl has a role in gastric digestion in the abomasum. Na and Cl involved with potassium in osmotic regulation and in acid–base balance	Pasture generally contains plenty of Na. Salt licks	Na and Cl absorbed from digestive tract. Any excess is secreted in urine. The kidney and the lower gut reduce excretion in urine and faeces when Na and Cl are in short supply

2. Microminerals

Mineral	Interfering factors	Function	Major sources	Notes
Copper (Cu)	Molybdenum, zinc, iron, selenium	Required for haemoglobin synthesis and involved in some enzyme and nerve formation. Also required for production of hair pigments and cartilage	Higher levels in clover	Absorbed from stomach, small intestine and large intestine. Toxicity uncommon in adults but can affect weight gain in milk-fed calves
Selenium (Se)	Vitamin E, iron	Important in microbial enzymes and tissue protein as well as antibody production (and therefore immune function)	Higher levels in grasses than clover. Se bullet	Absorbed from small intestines. Deficiency in adults linked with retained placenta and muscular weakness after calving. Muscular dystrophy associated with lack of Se or Vitamin E in calves. Toxicity causes death
Zinc (Zn)		Component of many enzymes and involved in many cellular functions	Zinc oxide, zinc sulfate	Absorbed in small intestine, efficiency of absorption low. Excess Zn lost in faeces. Toxicities rare
Sulfur (S)		Incorporated into the amino acids methionine, cystine and cysteine. Insulin and the vitamins thiamine and biotin also contain sulfur		Deficiency, which is rare, depresses digestion in rumen and food intake. Excess S plus high intake of Mo depresses the availability of Cu
Iodine (I)	Manganese, cobalt, calcium, goitrogens?	Required for synthesis of thyroid hormones that regulate rate of energy metabolism. Goitrogens found in some clovers inhibit hormone synthesis	Iodised salt licks	Absorbed very efficiently from the intestines. Excess is excreted in kidney. Deficiency causes reduced growth rates, reproductive failure and low milk production
Iron (Fe)	Calcium, phosphorus, copper, zinc	Major component of haemoglobin which is required for oxygen transport in the blood. Storage forms in muscle. Also required by several enzymes		Excess Fe harmful to Cu and phosphorus (P) metabolism. Blood loss from parasite burdens linked to deficiencies
Manganese (Mn)		Integral role in several enzymes. Required for bone and cartilage formation and fat and carbohydrate metabolism. Essential for growth, skeletal development, reproduction		Found throughout the body. Deficiency has been linked to reduced reproductive performance. Excess manganese interferes with Fe metabolism, depressing blood concentrations of haemoglobin
Cobalt (Co)		Component of vitamin B12 synthesised in rumen. All symptoms of deficiency are associated with a malfunction of enzymes that require vitamin B12	More in clover than grasses	B12 enzymes are responsible for propionate use in the liver. Deficiency leads to a loss in weight and milk production. Toxicities rare

Appendix 5 Tables of nutrient requirements

Information from these tables is required when completing Work sheet 4.

Energy requirements for maintenance

Table A5.1 Energy requirements for maintenance

Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Live weight (kg)	Energy requirements	
	MJ ME/day	kg TDN/day
100	17	1.2
150	22	1.5
200	27	1.9
250	31	2.2
300	36	2.5
350	40	2.8
400	45	3.1
450	49	3.4
500	54	3.8
550	59	4.1
600	63	4.4

Energy requirements for pregnancy

Table A5.2 Average daily energy requirements in the last four months of pregnancy

Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Month of pregnancy	Daily additional energy required	
	MJ ME/day	kg TDN/day
Sixth	8	0.6
Seventh	10	0.7
Eighth	15	1.1
Ninth	20	1.4

Energy requirements for activity

An allowance for grazing activity has been factored into the maintenance requirements in Table 5.1. In flat terrain, 1 MJ Metabolisable Energy (ME) (or 0.1 kg Total Digestible Nutrients (TDN) per kilometre should be added to provide the energy needed to walk to and from the dairy. In hilly country, this increases up to 5 MJ ME (or 0.4 kg TDN) per kilometre.

Energy requirements for milk production

For analyses of data comprising milk fat and milk Solids-Not-Fat (SNF), milk protein can be calculated as follows:

$$\text{Milk protein (\%)} = \text{SNF\%} - 5.4$$

Table A5.3 Energy needed per litre of milk of varying composition (MJ ME/L)
Metabolisable Energy (ME). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Fat (%)	Protein (%)									
	2.6	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**	**3.8**	**4.0**	**4.2**	**4.4**
3.0	4.5	4.5	4.6	4.7	4.8	4.8	4.9	5.0	5.0	5.1
3.2	4.6	4.7	4.7	4.8	4.9	5.0	5.0	5.1	5.2	5.2
3.4	4.7	4.8	4.9	4.9	5.0	5.1	5.2	5.2	5.3	5.4
3.6	4.9	4.9	5.0	5.1	5.1	5.2	5.3	5.4	5.4	5.5
3.8	5.0	5.1	5.1	5.2	5.3	5.3	5.4	5.5	5.6	5.6
4.0	5.1	5.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.8
4.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9
4.4	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9	6.0	6.0
4.6	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.1	6.2
4.8	5.6	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3
5.0	5.8	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4
5.2	5.9	6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5
5.4	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.7
5.6	6.2	6.2	6.3	6.4	6.5	6.5	6.6	6.7	6.7	6.8
5.8	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8	6.9	6.9
6.0	6.4	6.5	6.6	6.6	6.7	6.8	6.9	6.9	7.0	7.1

Table A5.4 Energy needed per litre of milk of varying composition (kg TDN/L)
Total Digestible Nutrients (TDN). (Source: Ministry of Agriculture, Fisheries and Food 1984)

Fat (%)	Protein (%)									
	2.6	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**	**3.8**	**4.0**	**4.2**	**4.4**
3.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
3.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
3.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
3.6	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
5.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
5.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
5.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
5.6	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5.8	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
6.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Energy requirements for changes in body condition

Table A5.5 The weight of one condition score on cows of different sizes
(Source: Target 10 1999)

Cow's approximate live weight (kg)	Additional weight to increase by one condition score (kg)
550	44
475	38
400	32

Table A5.6 The amount of energy needed or lost in a 1 kg gain or loss in body weight or condition
Metabolisable Energy (ME); Total Digestible Nutrients (TDN). (Source: Target 10 1999)

Change in body condition	Energy needed to gain 1 kg of weight (MJ ME or *kg TDN*)	Energy available from 1 kg of weight loss (MJ ME or *kg TDN*)
Late lactation gain	44 (*3.1*)	–
Dry period gain	55 (*3.9*)	–
Weight loss	–	28 (*2.0*)

Protein requirements

Table A5.7 Crude protein needs of a cow at different stages of lactation
(Source: Target 10 1999)

Milk production	Crude protein requirements
Early lactation	16–18%
Mid-lactation	14–16%
Late lactation	12–14%
Dry	10–12%

Fibre requirements

Table A5.8 The minimum percentage of fibre needed in a cow's diet for healthy rumen function (using three different measures of fibre)
(Source: Target 10 1999)

Fibre measurement	Minimum amount of dietary fibre (% DM)
Neutral detergent fibre	30%
Acid detergent fibre	19%
Crude fibre	17%

Appetite limits

Table A5.9 Maximum daily dry matter intake of cows (kg/d) as affected by cow live weight and diet Neutral Detergent Fibre (NDF) content

(Source: Linn and Martin 1989)

Live weight (kg)	NDF content (%)											
	25	30	35	40	45	50	55	60	65	70	75	80
100	4.8	4.0	3.4	3.0	2.7	2.4	2.2	2.0	1.8	1.7	1.6	1.5
150	7.2	6.0	5.1	4.5	4.0	3.6	3.3	3.0	2.8	2.6	2.4	2.3
200	9.6	8.0	6.9	6.0	5.3	4.8	4.4	4.0	3.7	3.4	3.2	3.0
250	12.0	10.0	8.6	7.5	6.7	6.0	5.5	5.0	4.6	4.3	4.0	3.8
300	14.4	12.0	10.3	9.0	8.0	7.2	6.5	6.0	5.5	5.1	4.8	4.5
350	16.8	14.0	12.0	10.5	9.3	8.4	7.6	7.0	6.5	6.0	5.6	5.3
400	19.2	16.0	13.7	12.0	10.7	9.6	8.7	8.0	7.4	6.9	6.4	6.0
450	21.6	18.0	15.4	13.5	12.0	10.8	9.8	9.0	8.3	7.7	7.2	6.8
500	24.0	20.0	17.1	15.0	13.3	12.0	10.9	10.0	9.2	8.6	8.0	7.5
550	26.4	22.0	18.9	16.5	14.7	13.2	12.0	11.0	10.2	9.4	8.8	8.3
600	28.8	24.0	20.6	18.0	16.0	14.4	13.1	12.0	11.1	10.3	9.6	9.0
650	31.2	26.0	22.3	19.5	17.3	15.6	14.2	13.0	12.0	11.1	10.4	9.8

Appendix 6 Exercises from the manual

The following exercises are based on a small holder dairy farmer with several feeds available for his herd of milking cows, all at different stages of their lactation cycle. Cows then differ in their levels of milk production and milk composition and their pregnancy status. Information for calculating cow requirements is presented in Chapter 6 and for formulating rations in Chapter 12.

Exercise 1

Using copies of the following Work sheet 4 provided, calculate the energy, protein and fibre requirements of four cows, all in stalls:

A A 550 kg cow in early lactation producing 20 L milk/d containing 3.6% fat and 3.2% protein. She is not pregnant and as she is using body condition to produce milk, she is losing 0.5 kg/day in live weight.

B A 500 kg cow in early lactation producing 17 L milk/d containing 3.6% fat and 3.2% protein. She is not pregnant and her body condition is stable so her live weight is not changing.

C A 500 kg cow in late lactation producing 5 L milk/d containing 4.0% fat and 3.8% protein. She is seven months pregnant and is gaining body condition at the rate of 0.5 kg/d.

D A non-lactating 500 kg cow. The cow is stalled in shed so has no activity allowance. She is nine months pregnant and is gaining body condition at the rate of 1.0 kg/d.

Work sheet 4: To calculate the daily energy, protein and fibre needs of a cow

The cow	Her energy needs (kg of TDN)	Her protein needs	Her fibre needs
Cow live weight A [ ] kg	For maintenance I [ ] kg	Early lactation 16–18% Mid-lactation 14–16% Late lactation 12–14% Dry 10–12%	(17% CF or 30% NDF)
Daily activity level B Terrain (1-5) [ ] kg/km	For activity [ ] X [ ] = J [ ] kg From B km		
Month of pregnancy D [ ] th Month	For pregnancy (Table 6.2) L [ ] kg		
Daily milk production E Volume [ ] Litres F Fat test [ ] % G Protein test [ ] %	For milk production (Table 6.3) From E [ ] X [ ] = M [ ] kg kg TDN/L		
Daily change in body condition H gain + loss - [ ] kg/cow /day	For or from condition (Table 6.5) [ ] X [ ] = N [ ] kg From H kg TDN/kg		

Total daily needs of this cow: Energy [ ] kg (I + J + L + M ± N) — Crude protein [ ] % from above — NDF or CF [ ] % from above

Exercise 2

A small holder farmer in Thailand has the following feeds available for his milking cows with prices in Thai Baht (Bt):

dry matter (DM); Crude Protein (CP); Crude Fibre (CF); Neutral Detergent Fibre (NDF); Metabolisable Energy (ME); Total Digestible Nutrients (TDN).

Feed	Price (Bt/kg)	DM (%)	CP (%)	CF (%)	NDF (%)	TDN (%)	ME (MJ/kg DM)
Immature grass	0.8	20	10	30	55	60	9.2
Mature grass	0.6	30	8	35	70	50	7.4
Legume	1.0	25	20	32	65	55	8.3
Corn silage	1.5	28	8	24	50	65	10.1
Rice straw	2.5	90	4	42	75	45	6.4
Formulated concentrate	5.0	90	18	15	25	75	12.0
Corn grain	4.0	85	10	7	8	80	12.9
Cassava chips	2.8	88	2	3	20	80	12.9
Rice bran Gr A	4.5	90	14	13	25	70	11.1
Cottonseed meal	5.2	90	45	13	35	75	12.0

The farmer wants to formulate a ration for Cow B (from Exercise 1). She is in early lactation, non-pregnant and producing 17 L/d of milk, which at 12 Bt/L generates a milk income of 204 Bt/d. The basal forage is immature grass and the main supplement is formulated concentrate. The farmer only wants to feed a total of 5 kg/d of concentrate supplements. This exercise involves using this range of feeds to formulate the cheapest ration for Cow B.

A Feeding 50 kg/d of immature grass plus 5 kg/d of formulated concentrate.
B Substituting 10 kg/d of the grass with legume and still feeding 5 kg/d of formulated concentrate.
C Feeding 50 kg/d of immature grass and substituting 1 kg/d of the concentrate with cottonseed meal.
D Feeding 50 kg/d of immature grass and substituting 1 kg/d of the concentrate with cottonseed meal and 1 kg/d with cassava chips.

Using copies of the following Work sheet 5 provided, calculate the energy, protein and fibre contents of these four rations, to provide the following information about each diet:

- total DM intake
- total TDN intake
- diet CP%
- diet NDF%
- intake limit (using Table 12.1)
- total feed costs
- milk income less feed costs.

Work sheet 5: To calculate the energy, protein and fibre content of a diet

Dry matter	Energy (TDN)	Protein (CP)	Fibre (NDF, CF)
Forage: ____ kg/d X ____ DM % ÷100 = A ____ kg/d	____ from A X ____ TDN % = F ____ kg/d	____ from A X ____ CP % ÷100 = J ____ kg/d	____ from A X ____ NDF/CF % ÷ 100 = O ____ kg/d
Supplement 1: ____ kg/d X ____ DM % ÷100 = B ____ kg/d	____ from B X ____ TDN % = G ____ kg/d	____ from B X ____ CP % ÷100 = K ____ kg/d	____ from B X ____ NDF/CF % ÷ 100 = P ____ kg/d
Supplement 2: ____ kg/d X ____ DM % ÷100 = C ____ kg/d	____ from C X ____ TDN % = H ____ kg/d	____ from C X ____ CP % ÷100 = L ____ kg/d	____ from C X ____ NDF/CF % ÷ 100 = Q ____ kg/d
Supplement 3: ____ kg/d X ____ DM % ÷100 = D ____ kg/d /cow/day	____ from D X ____ TDN % = I ____ kg/d	____ from D X ____ CP % ÷100 = M ____ kg/d	____ from D X ____ NDF/CF % ÷ 100 = R ____ kg/d
Total daily DM intake E ____ A+B+C+D kg Total daily DM intake limit ____ kg Use T and Table A5.9 or the formula (120÷T) ÷100 X live weight	Total daily energy intake ____ F+G+H+I kg	Total daily protein intake N ____ J+K+L+M kg CP % of ratio n ____ N÷E X 100	Total daily fibre intake S ____ O+P+Q+R kg NDF (CF) % of ration T ____ S÷E X 100
Cow requirements (from Worksheet 4)	Total daily energy requirement ____ kg	Crude protein requirement ____ %	Fibre requirement ____ % NDF/CF

Exercise 3

Using copies of the following Work sheet 6, calculate the cost of the TDN and protein in the four feeds from Exercise 2:

1 immature grass
2 corn grain
3 cassava chips
4 cottonseed meal.

Which feed provides the cheapest source of:

A energy
B protein.

Work sheet 6: The cost of nutrients in feeds (Baht)

Feed 1:

Cost per kg Dry Matter (DM)

[ ]	X	[ ]	X 100	=	A [ ]
kg bought		DM %			kg DM bought
[ ]	÷	[ ]	X 100	=	B [ ]
Total cost (Baht)		kg DM bought			Bt/kg DM

Cost per kg Total Digestible Nutrients (TDN)

[ ]	÷	[ ]		=	C [ ]
Bt/kg DM		TDN %			Bt/kg TDN

Cost per kg of Crude Protein (CP)

[ ]	÷	[ ]	X 100	=	D [ ]
Bt/kg DM		CP %			Bt/kg CP

Feed 2:

Cost per kg DM

[ ]	X	[ ]	÷ 100	=	A [ ]
kg bought		DM %			kg DM bought
[ ]	÷	[ ]	X 100	=	B [ ]
Cost (Bt)		kg DM bought			Bt/kg DM

Cost per kg TDN

[ ]	X	[ ]		=	C [ ]
Bt/kg DM		TDN %			Bt/kg TDN

Cost per kg of CP

[ ]	÷	[ ]	X 100	=	D [ ]
Bt/kg DM		CP %			Bt/kg CP

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