4

Feed production technology on smallholder dairy farms

This chapter quantifies the principles of dairy nutrition, namely the supply and requirements for water, energy, protein and fibre, then demonstrates the increase in cow performance through improved feeding.

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.
- High levels of dietary fibre can restrict voluntary intake hence cow performance.
- Feeding larger quantities of high quality grass can improve both milk yield and cow fertility.

This book is primarily about the human side of smallholder dairy farming, that is the farming family and their support structures. My first book (Moran 2005) concentrates on the production technology and in so doing, uses many technical terms and concepts related to quantifying the nutrient requirements of dairy stock, providing these needs and measuring the production responses in terms of milk, live weight gain and calves. For readers to fully comprehend the technical aspects of some chapters in this book, some basic understanding of the principles and measurement in dairy nutrition is desirable. Rather than duplicate the key chapters in *Tropical dairy farming* (Moran 2005), namely:

- Chapter 4: What is in feeds
- Chapter 5: How the rumen works
- Chapter 6: Nutrient requirements of dairy cows
- Chapter 7: How feed requirements change during lactation

this section provides a concise summary of these principles, sufficient to understand these concepts when discussed later in this book.

4.1 Feed nutrients required by 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, cannot. The rumen contains large numbers and many types of micro-organisms (often referred to as microbes). These microbes feed on plant material eaten by the cow and they 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 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.

Water. The body of a dairy cow is composed of 70–75% water. Milk is about 87% water. Water is not a feed as such because it does not provide specific feed nutrients. However, it is essential to regulate body temperature and 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.

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

Protein is the material that builds and repairs the body, its enzymes and 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.

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.

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	

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.

4.2 Sources of feed nutrients

4.2.1 Dry matter

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

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 $2 \div 0.2$ or 10% on a DM basis.

4.2.2 Energy

The energy in feed is a measure of that feed's ability to help the cow function and be productive. As feed energy is digested in the cow, various components are removed. The energy content of the feed when eaten is called its gross energy. Some of the gross energy is lost in the faeces leaving behind the digestible energy. From the digestible energy, further energy losses occur in the production of urine, as well as gas. All the remaining energy is known as metabolisable energy. Three measures of energy are digestibility, metabolisable energy and total digestible nutrients.

- **Digestibility**, measured as a percentage, 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. Because cows are able to digest and use more of it, the greater the digestibility, the greater the benefit of that food to the cow. The higher the digestibility, the higher the energy content.
- **Metabolisable energy.** The energy in a feed that a cow can actually use for its metabolic activities, that is maintenance, activity, pregnancy, milk production and gain in body condition, is called metabolisable energy (ME). The ME content of a feed can be calculated directly from its digestibility. The ME content of a feed (also called its energy density) is measured as megajoules of metabolisable energy per kg of dry matter (MJ ME/kg DM). Intake of ME is expressed in MJ/day. 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 kg of dry matter of that feed supplies 10 megajoules of metabolisable energy to the cow. A feed containing 12 MJ/kg DM then has a higher energy content than a feed containing 10 MJ/kg DM.
- **Total digestible nutrients (TDN)** is an alternative method to describe feed energy. This is a very old energy system but is still used in the US and some Asian countries. TDN 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. TDN is a less accurate measurement of energy than ME, because it does not take into account energy losses via methane (from rumen digestion) and urine. TDN content is expressed as a percentage, with TDN intake expressed in kg/d. The two systems are interchangeable (see Table 4.2 and 4.3) through the use of conversion equations as follows:

$$\mathrm{TDN} = 5.4\mathrm{ME} + 10.2$$

$$\mathrm{ME} = 0.185\mathrm{TDN} - 1.89$$

Throughout this book, references to the energy density of feeds will be given in these two measures, either as ME (as MJ/kg DM) and TDN (as %). References to cows' energy requirements or intakes will also be presented in these two measures, either as ME (MJ/day) or TDN (kg/day).

4.2.3 Protein

There are various ways to describe dietary protein, namely crude protein, non-protein nitrogen, rumen degradable and undegradable 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 as follows:

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

$$CP = N \times 6.25$$

- **Non-protein nitrogen (NPN)** is not actually protein, it is simple nitrogen. Rumen microbes use energy to convert NPN to microbial protein. In the forage-fed cows, however, the rumen microbes use NPN with only 80% efficiency (compared to the amino acids in true protein), which reduces the overall value of crude protein. Urea is a source of NPN.
- **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 of this RDP will be used to produce microbial 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's why UDP is sometimes called 'bypass protein'.

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

Table 4.4 Categories used to assess ability of feeds to supply undegradable dietary protein (UDP)

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

(Source: Target 10, 1999)

Nutritionists may want to know how much of the crude protein in the feed is RDP and how much is UDP. This analysis is called protein degradability. The degradability of protein in the diet depends on many factors including DM 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 RDP and UDP 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 UDP supply in feeds. This classification is shown in Table 4.4. A feed with lower RDP, hence higher UDP, has more milk production potential.

4.2.4 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 is 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. There are three methods of describing the fibre in feeds.

- **Neutral detergent fibre (NDF)** is a measure of all the fibre (the digestible and indigestible parts) and indicates how bulky the feed is. Some of it is digested, and some is excreted. A high NDF might mean lower intake because of the bulk while lower NDF values lead to higher feed intakes.
- **Acid detergent fibre (ADF)** is the poorly digested and indigestible parts of the fibre, i.e. the cellulose and lignin. If the ADF is low, the feed must be very digestible (i.e. high quality).
- **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 as a source of energy in the diet and as a substrate for some of rumen bacteria. However, it is commonly analysed because it is required in the calculation of TDN.

Sometimes the fibre in the diet is expressed as kg DM; but more often, fibre is expressed as % DM. For example, if a feed contains 25% NDF, one-quarter of its dry weight is fibre.

4.2.5 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, for production of enzymes, bone formation, milk production, reproduction and 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.

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.

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).

4.2.6 Essential nutrients and sources summary

Essential nutrients, their sources in feed and the units by which they are measured are summarised in Table 4.5.

Table 4.5 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 protein (UDP) Non-protein nitrogen (NPN)	Crude protein percent (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)

4.3 Predicting cow performance from nutrient intakes

Cows require nutrients to survive and be productive. It is possible to describe these requirements in terms of dietary energy, protein and fibre. Through knowledge of intakes of ME (or TDN) and the contents of protein and fibre in the total diet, the performance of a dairy cow can be predicted. Reference tables for energy, protein and fibre form Appendix 4 of this book, while Appendix 5 contains worksheets to allow calculations, either per cow per day or as a proportion of the total diet. Full details of how to undertake these calculations are presented in *Tropical dairy farming* (Moran 2005).

4.3.1 Water

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

Water requirements rise with air temperature. An increase of 4°C will increase water requirements by 6–7 L/day. High yielding milking cows can drink 150–200 L water/day during the hot season. There are many factors influencing water intakes such as DM intake, diet composition, humidity, wind speed, water quality (sodium and sulphate levels), and the temperature and pH of the drinking water.

4.3.2 Energy

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

Maintenance. Energy is used for maintaining the cow's metabolism. This includes breathing and maintaining body temperature. Physical activities such as walking and eating add to the maintenance requirement, as do environmental temperature and physiological state (i.e. pregnancy and lactation). With most cows in the tropics housed indoors, physical activity is negligible. Appendix Table A4.1 shows the energy needed for maintenance at various live weights, in terms of ME or TDN. These values include a 5% safety margin to take into account the energy required to harvest and chew the feeds. Cold stress is unlikely to directly influence the energy requirements of milking cows in South and East Asia. When animals are heat stressed to the point that they are panting, their energy requirements for maintenance can be increased by up to 10%.

Activity. On flat terrain, 1 MJ ME (or 0.1 kg 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.

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 approximately 1 MJ/day for each month of pregnancy. Energy requirements for pregnancy only become significant in the last four months. Appendix Table A4.2 shows the average daily energy requirements during these last months in both ME and TDN.

Milk production. Energy is the most important nutrient to produce milk. The energy needed depends on the composition of the milk (i.e. fat and protein content). The Appendix presents the energy needed to produce a litre of milk with a range of fat and protein tests, in both MJ of ME (Appendix Table A4.3) and kg of TDN (Appendix Table A.4).

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

$$\text{Milk protein (\%)} = \text{SNF\%} - 5.4$$

From Appendix Table A4.1 to Table A4.3, the ME requirements of:

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

are:

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

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, out of 8 points. A very thin cow might score 3 or lower while a fat cow might score 6 or greater. This body condition score system is fully described in *Tropical dairy farming* (Moran 2005).

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). Appendix Table A4.5 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.

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.

Appendix Table A4.6 shows how much energy is needed for condition gain and how much is released when condition is lost. Gaining a kilogram in the dry period takes more energy than gaining it in late lactation. Although it is worthwhile for cows to gain condition when dry, it is more efficient to feed extra energy during late lactation to achieve the desired condition score prior to drying off the cow.

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 ME (44 kg/condition score x 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.

From Appendix Table A4.1 to Table A4.6, the ME requirements of:

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

are:

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

For another cow, the ME requirements of:

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

are:

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

4.3.3 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. Appendix Table A4.7 shows crude protein needs at different levels of milk production. As discussed earlier, protein is measured as crude protein, which is the sum of RDP plus UDP.

When calculating the protein requirements of the herd, crude protein, RDP or UDP figures can be used. Remember though that requirements for RDP and UDP are only 'guesstimates'. To work out how much RDP and UDP 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 (i.e. UDP). However, not all microbial protein or UDP 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, RDP and UDP requirements can only be calculated estimates.

Above a certain level of milk production, some protein in the diet must be UDP. There is a limit to the rumen's capacity to use RDP 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 to 12 kg/day. In other words, when milk production is 12 L/day or less, all the protein in the diet can be RDP (i.e. protein that the microbes can use). However, for milk production over 12 kg/day, at least some protein in the diet must be UDP.

4.3.4 Fibre

Cows need a certain amount of fibre in their diet to ensure that the rumen functions properly and to maintain the fat test. Appendix Table A4.8 shows the levels of fibre cows need in their diet. It should be stressed that the fibre requirements listed are the absolute minimum values. Acceptable levels of NDF in the diet are in the range 30–35% of DM.

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 exceeds 4–5 kg grain/cow/day. Buffers are not a substitute for fibre. Long-term feeding of low-fibre diets should be avoided. Appendix Table A4.9 presents the maximum daily intake as influenced by the NDF content of the total diet. These data were derived from high yielding cows fed feedlot rations based on temperate forages, so they are only a guide as to the likely effects of the content of NDF in the total ration on predicted voluntary feed intake of cows in tropical smallholder dairy farms.

4.4 Increasing dairy farm profitability through improved pasture technology

Growing quality forages is the key to profitable dairy production throughout the world, whether it be an intensive dairy feedlot in the US (where sourcing these quality forages at a competitive price is the issue), a heavily stocked grass-based dairy in southern Australia or a smallholder farm in South-East Asia. In all cases forages are generally cheaper than concentrates and the more feed nutrients that stock can consume in their forage base, the fewer are required from the purchased concentrates.

A recent paper from Vietnam has provided additional evidence of the potential benefits arising from improved grass technology (Mui *et al.* 2003). Around three major cities in Vietnam, feed costs comprise 50% (Hanoi) to 64% (Saigon) to 68% (Hatay) of the total production costs for peri-urban dairy farmers. Green feed can reduce feed costs by replacing concentrate ingredients and increasing milk yield. Because only 10% of the farmers grow grass for livestock fodder, farmers are forced to use dry and fresh rice straw to meet the shortfall, frequently reducing cow performance.

Figure 4.1 Well-managed Guinea grass (left) and Napier grass (right), requiring different harvest intervals (South Vietnam)

Farmers are encouraged to use correct fertiliser levels, which Mui *et al.* (2003) report in field plots, can increase yields of Napier grass (*Pennisetum purpureum*) from 150–400 t fresh/ha/yr (or 26–69 t DM/ha/yr). More realistic commercial yields are 250 t fresh or 42 t DM/ha/yr from six harvests per year. Another high yielding pasture species is Guinea grass (*Panicum maximum*) which can produce 148 t fresh or 28 t DM/ha/yr.

Not only are high forage yields possible through this improved grass technology, but cow performance also improves. Table 4.6 presents data from 91 cows either fed rations based on less than 10 kg/d fresh grass or over 20 kg fresh/d. Unfortunately the authors did not present the DM contents of the various diet ingredients, making it difficult to accurately calculate the percentage of grass in the diet DM.

Feeding more grass (1.5 to 4.1 kg DM/cow/d) increased milk yields from 10.7 to 15.2 kg/d, reduced the number of services per conception and the days from calving to mating.

Additional data suggest that a reasonable economic efficiency can be achieved in crossbred Friesians when fed 28–36 kg Napier grass in their diet, with cows producing 3000–3500 L/lactation.

One way of promoting the improved technology is through 'grass fairs', attended by dairy farmers and suppliers of grass seedlings, fertilisers and pesticides. This enables farmers to buy high quality, high yielding grass seedlings. Farmers can grow grass for sale to the peri-urban farmers, selling the forage for 150–300 VND/kg fresh, although this can increase to 500 VND/kg in areas of high demand.

Table 4.6 Effect of forage intake on dairy cow performance (Mui *et al.* 2003)

	Ration A	Ration B
Feed (kg/cow/d)		
Grass	9.6	24.0
Concentrate	5.1	5.6
Brewer's grain	9.2	8.9
Soybean residue	5.8	4.7
Cassava waste	4.2	7.1
Pineapple peels	5.4	–
Rice straw	5.0	3.0
Sugar cane tops	7.0	9.0
Cow performance		
Milk yield (kg/cow/d)	10.7	15.2
Insemination/conception	2.1	1.7
Days calving to 1st oestrus	79	74
Days calving to mating	102	90
Days calving to pregnancy	133	144

Table 4.6 clearly demonstrates how relatively simple improved technology, namely pasture species and fertilisers, can greatly benefit smallholder dairy farmers.

4.4.1 Recent sources of information on tropical forages

In recent years, several excellent sources of information have been developed to assist with forage selection for Asian livestock producers. These include:

1. A concise bulletin on selecting forages for livestock feeding in South-East Asia was published by Horne and Stur (1999).
2. The growing and conserving of quality tropical forages for Asian smallholder dairy farmers has been covered in detail in Chapters 8 and 9 of *Tropical dairy farming* (Moran 2005).
3. A CD on which is presented a process for forage species selection based on their optimum climate, soils, production system and management (Cook *et al.* 2005).
4. A CD on which is collated the FAO database of 600 species of tropical forages and legumes (FAO 2005a).
5. A CD on which is collated the profiles of 14 Asian countries detailing their climate, livestock and forage resources (FAO 2005b).