5

The principles of dairy nutrition

This chapter explains the key principles of dairy nutrition to better understand the practices of feeding management.

The main points in this chapter

- Feeds contain the nutrients for animal survival and production: the most important ones being water, energy, protein and fibre.
- There are several ways to describe the energy concentration of feeds, with metabolisable energy being the preferred method.
- Feed protein and fibre can also be described in various ways.
- Feeds can be categorised into various types depending on their nutrient composition. One good classification system is based on their energy and protein contents.
- It is possible to calculate the nutrient requirements of milking cows to produce target levels of milk.
- Understanding the lactation cycle, from one calving to the next, is important when planning and managing the herd's annual feeding program.

The essence of good farm management is to supply sufficient farm inputs for a desired level of production of farm outputs. For SHD farmers this means setting realistic milk production targets, each day, each month or each year and determining the necessary farm requirements to achieve these targets. The major requirements for sustainable milk production are healthy, productive and fertile dairy cows and their required feed nutrients supplied in forages and concentrates. The forages are either grown on farm or purchased. The concentrates are usually purchased, either already formulated or as their ingredients, the latter usually as agro-industrial by-products.

Other chapters in this manual discuss the important aspects of good dairy herd management, while the following two chapters discuss their feeding management. This chapter explains the principles of dairy nutrition, while the following chapter discusses the feeding management of the milking herd.

Feeding management includes both the supply of feeds and their presentation to the milking cow. The chapters on soil and forage management and on silage making deal

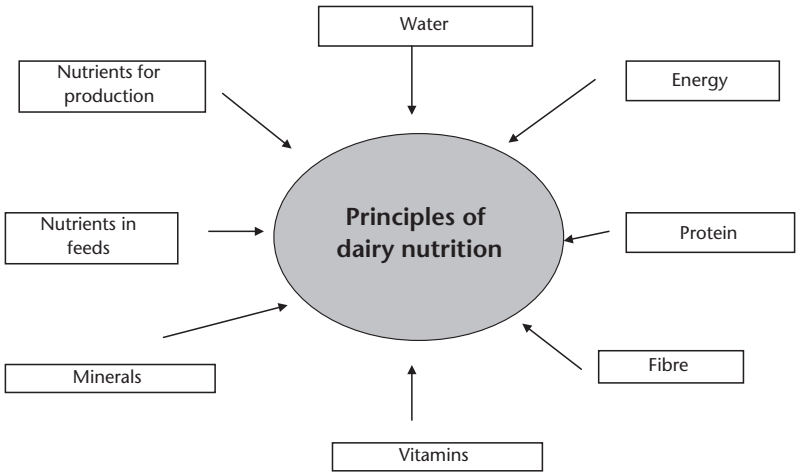

Figure 5.1. The key elements of dairy nutrition

with on-farm feed supplies. This chapter discusses the processes involved in calculating how much feed is required to achieve milk production targets.

Dairy cows are herbivores and have digestive systems well adapted to forage-based diets. Belonging to a group of mammals called ruminants, they have a multi-purpose digestive system. As well as a stomach that breaks feeds down into their basic nutrients, they have a rumen, which is like a large 'fermentation vat' where micro-organisms pre-digest these feeds. The rumen of a mature dairy cow is up to 200 L in volume where the feeds can spend 12 to 24 hr before moving onto the 'true' stomach.

5.1 Nutrients supplied by feeds

When cows consume their smorgasbord of feeds, the major nutrients they extract from them are water, energy, protein, fibre, vitamins and minerals. The four nutrients that have the major influence on cow performance are water, energy, protein and fibre.

1. **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 nutrients. However, it is essential in body processes and to regulate body temperature. 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.
2. **Energy.** Dairy cows use energy to function (to walk, graze, breathe, grow and put on body condition, lactate and maintain a pregnancy). Energy is the key requirement of dairy cows for milk production. It determines milk yield and milk composition.
3. **Protein.** Protein is the material that builds and repairs the body's enzymes and hormones, and is a constituent of all tissues (muscle, skin, organs and 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 various nitrogen-containing

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.

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 parts of the diet. It ensures that the cow chews its cud (ruminates) enough and therefore salivates. Saliva buffers the rumen against sudden changes in acidity.
5. **Vitamins.** These 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, such as the production of enzymes, bone formation, milk production, reproduction and disease resistance.
6. **Minerals**. These inorganic elements are needed for teeth and bone formation, enzyme, nerve, cartilage and muscle function or formation, milk production, blood coagulation and efficient utilisation of energy and protein.

5.1.1 Describing feed energy

There are various ways to describe the energy content in feeds and these are briefly discussed below.

1. **Digestibility.** Measured as a percentage, digestibility relates to the portion of food that 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.
2. **Metabolisable energy (ME).** This describes the energy in a feed that cows can actually use for their metabolic activities; that is, maintenance, activity, pregnancy, milk production and gain in body condition. 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 contains 10 MJ of metabolisable energy available for use by the cow. A feed containing 12 MJ/kg DM then has higher energy content than a feed containing 10 MJ/kg DM.
3. **Total digestible nutrients (TDN).** This is an alternative method to describe feed energy. This is a very old energy system, but still used in the US and some Asian countries. 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/day. TDN and ME are interchangeable.

References to the energy density of feeds are given in either of these two measures, as ME (as MJ/kg DM) and TDN (as %). References to cows' energy requirements or intakes are also given in these two measures, either as ME (MJ/day) or TDN (kg/day). This manual will use the ME system because it is more frequently used by dairy nutritionists.

5.1.2 Describing feed protein

There are various ways to describe dietary protein and these are briefly discussed below.

1. **Crude protein (CP).** 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 using the formula $CP = N \times 6.25$.
2. **Non-protein nitrogen (NPN).** NPN is not actually protein, it is simply nitrogen. Rumen microbes use energy to convert NPN to microbial protein for use in the body. In forage-fed cows, the rumen microbes use NPN with only 80% efficiency (compared with true protein), which reduces its overall value as a protein source. Urea is a source of NPN.
3. **Rumen degradable protein (RDP).** This 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.
4. **Undegradable dietary protein (UDP).** This 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'. The proportion of the protein that is digested in the rumen is called its degradability.

5.1.3 Describing feed fibre

There are various ways to describe dietary fibre and these are briefly discussed below.

1. **Neutral detergent fibre (NDF).** This 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.
2. **Acid detergent fibre (ADF).** This is the poorly digested and indigestible parts of the fibre; that is, the cellulose and lignin. If the ADF is low, the feed must be very digestible (i.e. high quality).
3. **Crude fibre (CF).** Although sometimes used to indicate fibre content, CF 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 the rumen bacteria. However, it is commonly analysed because it is required in the calculation of TDN.

5.2 Nutrients contained in feeds

Most dairy cattle nutritional reference books contain tables of the nutritive value of feeds and supplements. The following two tables provide a summary of some of the common forages (Table 5.1) and supplements (Table 5.2) fed to dairy cows in Asia (Moran 2005). The values are in ranges to take into account differences in the agronomic growing conditions and stage of maturity in forages and the degree of processing of by-products. Table 5.3 classifies feeds on the basis of their average CP and ME contents.

Table 5.1. Nutritive values of some common Asian forages

Forage	DM (%)	ME (MJ/kg DM)	CP (%)	NDF (%)
Grasses				
Napier grass (immature)	13–15	8–9	11–15	60–70
Napier grass	18–25	7–9	10–12	65–75
Rhodes grass	20–25	7–9	8–10	65–75
Guinea grass	20–25	7–9	10–12	65–75
Para grass	25–30	7–9	10–12	65–75
Forage sorghum	13–15	7–9	11–15	65–75
Native pasture	25–35	7–9	8–10	60–70
Leucaena leaf	28–32	7–9	18–26	40–50
By–products				
Maize stover	18–25	7–8	6–8	60–70
Cassava hay	85–90	8–9	22–25	50–60
Peanut leaf and stem	26–30	9–10	18–20	50–60
Soybean leaf	26–30	10–11	20–24	50–60

Ample supplies of quality grass are the basis of profitable dairy farming (Vietnam).

Table 5.2. Nutritive value of some common Asian supplements

Feed	DM (%)	ME (MJ/kg DM)	CP (%)	NDF (%)
Energy				
Cassava chips	85–90	12–13	2–3	5–10
Maize (grain)	85–90	13–14	10–12	8–10
Rice bran (good quality)	85–90	11–12	13–14	25–35
Rice bran (poor quality)	85–90	8–10	8–10	30–50
Sweet potatoes	30–35	12–13	5–6	20–30
Cassava waste (fresh)	20–24	7–8	2–3	20–25
Wheat pollard	85–90	11–12	14–16	30–40
Brewers grain	25–30	10–11	25–30	50–60
Commercial concentrate	85–90	11–12	15–18	12–25
Protein				
Soybean meal	85–90	13–14	45–50	25–35
Coconut meal	85–90	12–13	15–25	40–50
Cottonseed meal	85–90	12–13	40–45	30–40
Palm kernel cake	85–90	11–12	14–16	60–70
Soybean curd (fresh)	13–15	13–14	20–25	25–35
Urea	100	–	280	–
Forage				
Rice straw	85–90	6–7	4–6	65–75
Urea-treated rice straw	85–90	8–9	7–8	65–75
Banana stem	5–8	9–10	3–4	60–70
Sugar cane tops	25–30	7–9	5–6	65–75

Table 5.3 provides a ready reckoner to consider when seeking feeds to balance cows' diets that may be low in dietary energy or protein.

5.3 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 energy and the contents of protein and fibre in the total diet, the performance of a dairy cow can be predicted.

5.3.1 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 litre 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. Other factors influencing water intakes include DM intake, diet

Table 5.3. Classification of supplements and basal forages according to their energy and protein contents

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 Maize stover Sugar cane tops Cassava waste	Rice bran (poor) Most grasses Sweet corn cobs Banana stem Urea-treated rice straw	Cassava chips Paddy rice Molasses Sweet potatoes Pineapple waste Maize silage
Moderate protein (10–16% CP)	–	Brown rice Well-managed grasses Soybean Immature grasses	Maize grain Sorghum grain Rice bran (good) Wheat pollard Palm kernel cake
Good protein (<16% CP)	Urea	Whole cottonseed Shrimp waste Cassava hay Most legumes Legume hays	Brewers grain Coconut meal Soybean curd Commercial concentrate Protein meals Legume leaves

Continual access to fresh drinking is essential for dairy cows (Pakistan).

Table 5.4. Energy requirements of small holder's milking cows (in MJ/day of ME) at different stages of lactation and pregnancy status

Description	Cow details						
	Cow 1	**Cow 2**	**Cow 3**	**Cow 4**	**Cow 5**	**Cow 6**	**Cow 7**
Live weight (kg)	550	550	550	550	500	500	500
Month of pregnancy	Empty	Empty	Empty	3rd	6th	7th	9th
Milk production (kg/day)	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/day)	–0.5	0	0	0	0	+0.25	+1.0
Energy requirements (MJ/day)							
Maintenance	59	59	59	59	54	54	54
Activity	0	0	0	0	0	0	0
Pregnancy	0	0	0	0	8	10	20
Milk production	*20 × 5.1* = 102	*17 × 5.1* = 87	*13 × 5.1* = 66	*10 × 5.1* = 51	*8 × 5.5* = 44	*5 × 5.5* = 27	0
Weight gain or loss	*–0.5 × 28* = –14	*0*	*0*	*0*	*0*	*0.25 × 44* = +11	*1.0 × 55* = +55
Total energy requirements	147	146	125	110	106	102	129

composition, humidity, wind speed, water quality (sodium and sulphate levels), and the temperature and pH of the drinking water.

5.3.2 Energy

Cows need energy for maintenance, activity, pregnancy, milk production and for body condition. It is beyond the scope of this manual to describe the detailed calculations required to estimate the energy requirements for dairy cows to achieve set production targets. However, to formulate any ration for such target production levels, such calculations are necessary. For readers to follow them up, they are described in detail in my earlier book (Moran 2005).

Table 5.4 presents example of these calculations to determine energy requirements for seven different cows, with varying live weight, pregnancy status and changes in live weight, to produce target yields of milk some with different milk fat and protein concentrations. The energy requirements are expressed in MJ of ME per day.

Dairy farmers and advisers involved in formulating rations for milking cows should seek assistance to ensure the rations they plan to feed provide sufficient energy for cows to achieve production targets.

5.3.3 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. Cows in early lactation require 16–18% CP in their diet and this decreases to 14–16% in mid-lactation, to 12–14% in late lactation and 10–12% during the dry period.

5.3.4 Fibre

Cows need a certain amount of fibre in their diet to ensure that the rumen functions properly and to maintain the fat test. Acceptable levels of neutral detergent fibre (NDF) in the diet are in the range of 30–35% of dry matter (DM).

5.4 The lactation cycle

Cows must calve to produce milk and the lactation cycle is the period between one calving and the next. The cycle is split into four phases: the early, mid and late lactation (each of about 120 days) and the dry period (which should last as long as 65 days). In an ideal world, cows calve every 12 months.

A number of 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. Figure 5.2 presents the interrelationships between feed intake, milk yield and live weight for a Friesian cow with a 14-month inter-calving interval, hence a 360 day lactation.

Following calving, a cow may start producing 10 kg/day of milk, rising to a peak of 20 kg/day by about 7 weeks into lactation then gradually fall to 5 kg/day 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. 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

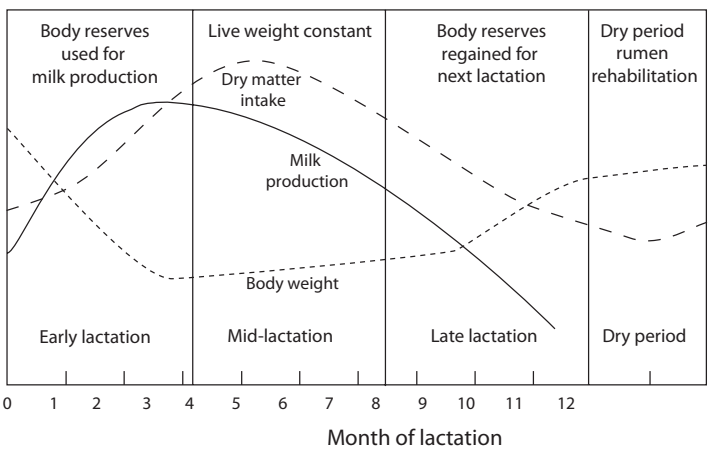

Figure 5.2. Dry matter intake, milk yield and live weight changes in a cow during her lactation cycle

their diet alone. To do this, cows must have sufficient body condition available to lose, and therefore they must have put on weight late in the previous lactation or during the dry period.

5.4.1 From calving to peak lactation

Milk yield at the peak of lactation sets up the potential milk production for the year; one extra kg per day at the peak can produce an extra 200 kg milk/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 a number of 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 50–70% 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 10–12 that appetite reaches its full potential.

5.4.2 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. From Figure 5.1, cows tend to maintain weight during this stage of their lactation.

5.4.3 Mid and 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 efficient to improve the condition of the herd in late lactation rather than in the dry period.

5.4.4 Dry period

Maintaining (or increasing) body condition during the dry period is the key to ensuring cows have adequate body reserves for early lactation. If cows calve with adequate body reserves, they can cycle within 2–3 months after calving. If cows calve in poor condition, milk production suffers in early lactation because body reserves are not available to contribute energy. In fact, dietary energy can be channelled towards weight gain rather than 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.

5.5 Proportion of productive cows in the milking herd

One good measure of the performance of the milking herd is the proportion of cows actually producing milk. For herds with a 12-month calving interval, the lactation length should be 300 days (for a 65-day dry period), so the lactation length would be the calving interval minus 65 days, meaning that 82% of the cows are milking at any one time with a

Table 5.5. Percentage of days milking as influenced by calving interval and lactation length

Calving interval (days)	Dry period (days)	Lactation length (days)	% days milking
365	65	300	82
	90	275	75
	115	250	68
400	65	335	84
	100	300	75
	125	275	69
	150	250	62
450	65	385	86
	115	335	74
	150	300	67
	175	275	61
	200	250	55

100% calving rate. However, in most year-round calving systems, only a maximum of 74% of the adult cows (including the first calf heifers) are likely to be milking. The longer the dry period, the fewer the number of cows milking at any one time. The number of cows milking at any one time is influenced by several factors, the most important ones being lactation length, inter-calving interval and calving rate. Guidelines for tropical dairy farmers are:

- 74%; excellent
- 60–73%; acceptable
- 50–59%; below average
- 40–49%; not good.

One good way to demonstrate the importance of having as many of the adult cows milking as possible is to develop a table, like Table 5.5, in which the percentage of days any one cow is milking is related to the herd's inter-calving interval, the length of the dry period, hence the average lactation length. This is essentially the same as calculating the percentage of adult cows milking for a 100% calving rate.

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