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

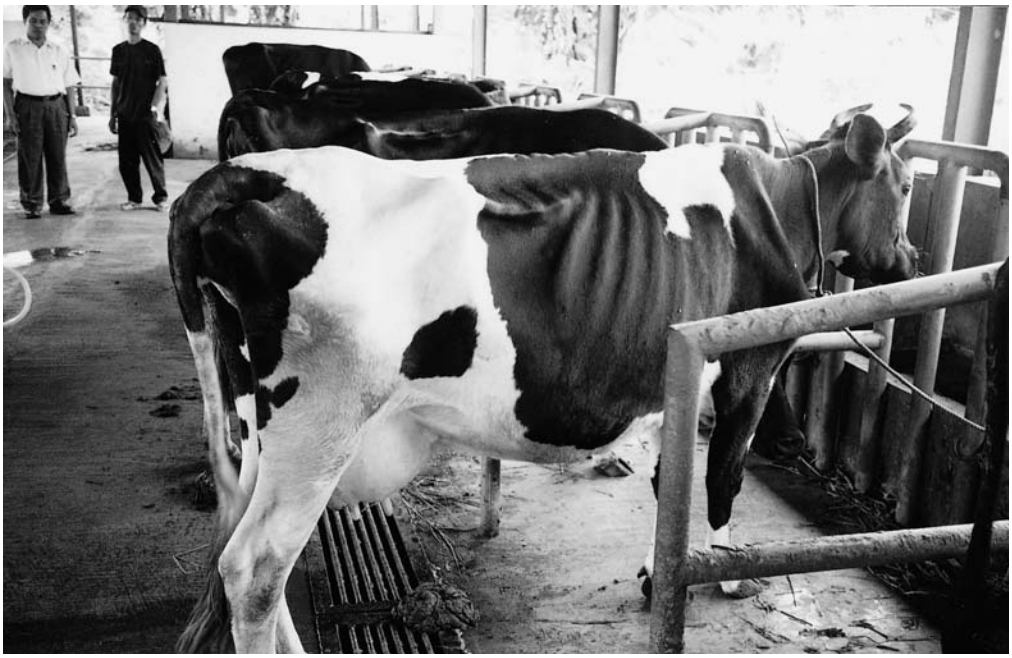
A pregnant cow needs extra energy for the maintenance and development of the calf inside her. From conception through the first five months of pregnancy, the additional energy required is about 1 MJ/d for each month of pregnancy. Energy requirements for pregnancy become significant only in the last four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

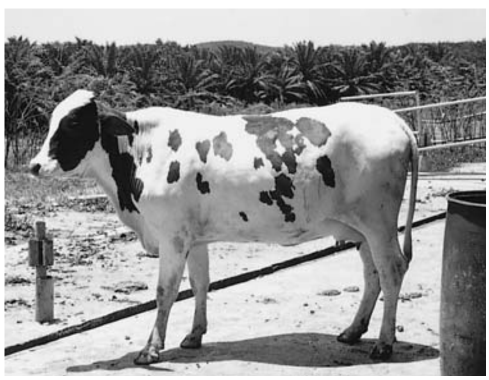
Milk production	Crude protein requirements (%)
Early lactation	16–18
Mid-lactation	14–16
Late lactation	12–14
Dry	10–12

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.