

4

The nutrient requirements of calves

This chapter describes the various feed nutrient calves require for normal growth (Figure 4.1).

The main points in this chapter

- Water is essential for all living animals. Weaned calves require 10–15 L/day with up to 25 L/day on hot days.
- Energy is required to maintain body temperature and to support normal body function. Energy is best described as metabolisable energy (ME), with requirements quantified in MJ of ME/day.
- Milk is digested in the abomasum with much higher energetic efficiency than are solid feeds in the rumen.
- Proteins are required to maintain normal body processes, repairing tissues and forming blood and also laying down muscle. Protein is quantified in g/day or percentage of feed dry matter.
- Rumen development in the milk-fed calf depends on its intake of solid feeds that contain fibre.
- Calves also require small amounts of minerals and vitamins. The most important minerals are calcium, phosphorus and magnesium.

The three most essential nutrients for calf growth and development are water, energy and protein. Fibre, minerals and vitamins are also needed, but play a smaller role.

4.1 Water

Water is essential for all living animals and it is good husbandry to provide calves with as much fresh, clean water as they want. Weaned calves can drink 10–15 L/day and up to 25 L/day on hot days. For optimum feed efficiency, milk-fed calves need to drink 4 L of water for every kg calf concentrate they eat.

Milk contains 87–88% water, which should be sufficient for normal body requirements. Milk-fed calves will not suffer from the absence of extra water unless they

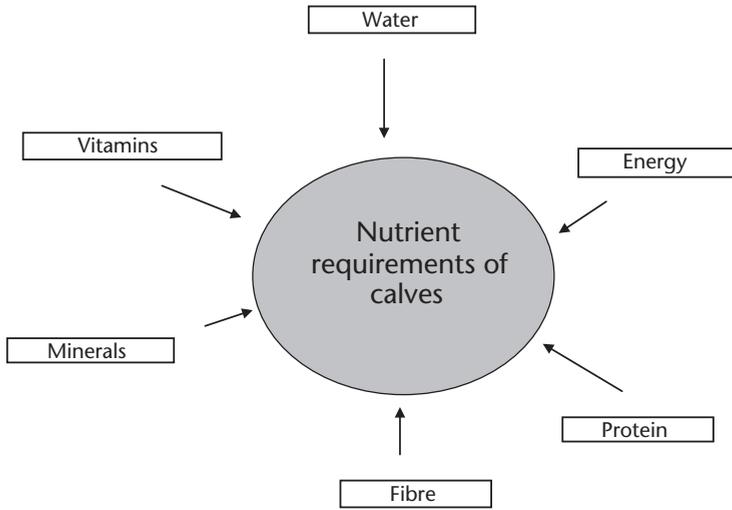


Figure 4.1. The nutrient requirements of calves

are exposed to heat stress. However, as soon as they start eating solid feeds, particularly dry feeds like hay or straw, calves require continuous or regular access to fresh water. This simple practice will increase their intake of solid feeds and so reduce their age at weaning.

To standardise the description of feed intake, it is usually expressed in terms of dry matter (DM). This is easily measured by placing feeds in an oven at 100°C for up to 48 hr. Animals eat quite similar amounts of DM no matter what type of feed is offered.



Continual access to fresh drinking is essential for all dairy stock.

Maximum DM intake is directly related to live weight. Setting a maximum value of 2.5–3.0% live weight per day, a 100 kg weaned calf will eat about 3 kg DM/day while a 200 kg calf would eat up to 6 kg DM/day.

4.2 Energy

Energy is needed to maintain body temperature and to support normal body functions. This is known as the maintenance energy requirement. Any energy consumed that is surplus to this basic need is available for growth or the laying down of muscle and fat, which leads to live weight gain. Maintenance energy requirements increase with live weight.

Energy requirements and the available energy in feeds are measured in units called joules, and more commonly in kilojoules (1000 joules) or megajoules or MJ (1 million joules).

Only a portion of the total (gross) energy in feeds becomes available to the calf following its digestion. Undigested energy is lost in the faeces, while a small portion of the digested energy is lost through rumen fermentation and also in the urine.

The remaining useful productive energy is called the metabolisable energy or ME. This is the conventional measure of the energy requirements of the calf (in MJ of ME/day) and also the energy content of different feeds (in MJ of ME/kg dry matter or MJ/kg DM).

Because milk is a high-quality feed that is digested efficiently in the abomasum, its energy value to the calf is considerably greater than that of solid feeds digested in the rumen. More than 90% of the gross energy in milk ends up as ME compared with only 50–60% of the gross energy in hay and concentrates.

The energy requirements for growth increase with age and live weight. They also vary with the energy content of the feed. High energy feeds, such as milk and concentrates, are used more efficiently for growth than low energy feeds, such as medium quality pasture or hay. Because the maintenance ME requirement is relatively constant for a particular live weight, the faster an animal grows, the higher the proportion of the total ME intake is available for growth, and therefore the more efficiently the feed is used by the calf.

For example, an 80 kg weaned calf growing at 0.5 kg/day requires 44 MJ for each kg of weight gain, and will only use 32% of its ME intake for growth. If growing at 1.0 kg/day, it requires only 31 MJ for each kg of weight gain and will use 52% of its ME intake for growth. Furthermore, it will only take half the time to achieve the same target live weight gain. The slower growing calf will then require considerably more ME than is apparent from the difference between these two ME requirements for growth. This highlights the greater value of any high-quality feed to achieve improved growth rates.

Calculations on the energy requirements of milk-fed calves differ from those for calves with developed rumens. A milk-fed calf weighing 100 kg and growing at 0.5 kg/day requires a total of 21 MJ of ME per day, 4 MJ/day less than if that calf was weaned. For calves fed milk, about 20% of the gross energy in milk is retained in the body of a 2-week-old calf growing at 0.3 kg/day, and this can increase to 26% for 14-week-old veal calves fed milk replacer and growing at 1.2 kg/day. However, only 11% of the gross energy

intake is retained in the bodies of 6-month-old calves already weaned onto a diet of hay and concentrate, and growing at 0.6 kg/day.

In other words, solid feeds digested in the rumen are only used about half as efficiently by the growing calf as milk digested in the abomasum. However, the energy in milk can cost up to four times that in concentrates, making early weaning onto solid feeds considerably cheaper than milk feeding. This is discussed further in Chapter 15.

The reason that feed energy is the most important nutrient in any diet is because the efficiency of feed energy conversion into animal product is so low. Less than a quarter of the energy in milk fed to calves is retained by the animal and this falls to only one tenth of the solid feed when the calf is weaned. Once energy is used by the animal, some of it is lost as body heat, while some of the other feed nutrients are recycled within the animal.

Practical ration formulation is based on the principal of selecting the most appropriate ration ingredients to meet the animal's energy needs at the lowest cost. Requirements for the other nutrients, such as protein, fibre and minerals, can then be met by adjusting the concentration of the ration ingredients so that none of these limit animal performance. Table 4.1 shows examples of calculations on the energy and protein requirements for weaned calves to achieve various growth rates at different live weights. This table was first presented by Webster (1984) using standard feeding tables published in the UK by Agricultural Research Council (1980). In Asia, the energy and protein requirements for ruminants are often calculated using the US National Research Council (1989) standards.

Table 4.1 shows that the ME intakes of calves achieving 1.0 kg/day weight gain are only about a third higher than for calves growing at 0.5 kg/day, but about double those for maintenance. This table also presents the required ME and crude protein (CP) contents of any ration to achieve growth rates of 0.5 or 1.0 kg/day.

4.3 Protein

Proteins are required by the calf to maintain biological processes on a daily basis, as well as repairing tissues and forming blood. Proteins are also an integral part of growth, such as the laying down of muscle. Most protein synthesis takes place in other body tissues such as the liver and gut wall, which are actively concerned with processing nutrients to meet the requirements of the body. These metabolic functions include such things as synthesis of enzymes and hormones, cell division and cell repair, and so require a continuous supply of different types of protein and energy.

The building blocks of all proteins are amino acids. There are more than 20 specific amino acids needed by livestock. Feed protein is broken down by digestion into its individual amino acids, which the calf absorbs and then resynthesises for its maintenance and growth.

The precise needs for specific amino acids are well known in non-ruminants such as pigs and poultry but there is little information available on the amino acid requirements of calves and adult ruminants. Because the milk-fed calf depends entirely on its diet to supply them, the amino acid composition of whole milk would probably match its specific requirements.

Table 4.1. Requirements of weaned calves for metabolisable energy (ME), rumen degradable protein (RDP) and undegradable dietary protein (UDP) at different live weights and for different growth rates (prepared by Webster 1984)

	Live weight (kg)		
	80	140	200
Maximum DM intake (kg/day)	2.4	3.6	4.8
ME requirements (MJ/day)			
Maintenance (M)	15	23	30
M + 0.25 kg/day gain	18	27	36
M + 0.5 kg/day gain	22	32	42
M + 0.75 kg/day gain	26	38	48
M + 1.0 kg/day gain	31	43	55
Minimum dietary ME content (MJ/kg DM)			
0.5 kg/day gain	9.2	8.9	8.7
1.0 kg/day gain	12.9	11.9	11.5
Crude protein requirement (g/day)			
0.5 kg/day gain RDP	170	250	330
UDP	130	120	110
1.0 kg/day gain RDP	240	335	430
UDP	200	180	150
Minimum dietary crude protein content (%)			
0.5 kg/day gain	12.5	10.3	9.2
1.0 kg/day gain	18.3	14.3	12.1

Rumen microbes synthesise many of these amino acids in the older calf, during the formation of microbial protein, while others are provided by the undegraded protein in the diet. Although the essential role of amino acids is in forming proteins, they can be used as sources of energy when they are in excess to the calf's protein requirements. In other words, if more protein is fed than required, it is used for energy in much the same way as the starch in cereal grains or other energy sources. However, because protein is usually more expensive than energy to supply in feeds, it is important to provide only that amount required when formulating rations.

The element nitrogen (N) is an essential constituent of all proteins, present at about 16% of the DM, though varying slightly with different proteins. That is why when feeds are analysed for protein, the total N content is measured then multiplied by 6.25 (or 100/16) to give the level of crude protein, or 6.38 where milk products are concerned. This is a good measure of the capacity to provide amino acids in many feeds, but, in others, much of the crude protein is in the form of non-protein N, usually simple compounds such as urea. All feeds contain some proportion of their N as non-protein N.

Adult ruminants can benefit from this non-protein N because, when it is broken down by the rumen microbes into ammonia, they re-use it to synthesise their own microbial protein. In calves up to 6 months old, the crude protein should be mainly in the form of true protein. The nearer the composition of a feed protein is to that of the

protein in calf weight gains, the more efficiently it can be used by the calf for growth because the supply of amino acids will more closely match its requirement. In other words, there will be less likelihood of any amino acids limiting calf performance or of excess amino acids being wasted as protein sources. The extent to which the true protein is broken down by microbial action depends on its vulnerability to microbial attack and the length of time it spends in the rumen.

Animal proteins, such as fish meal, are more valuable to calves than plant proteins because their amino acid make up more closely matches those of the rapidly growing calf. This is called the biological value of the protein for animals. However, it is now illegal to use animal proteins to feed ruminants in most countries because of the concern that they are associated with the spread of certain diseases such as ‘mad cow disease’.

Dietary crude protein is further described in terms of two constituents, namely rumen degradable protein (RDP) and undegradable dietary protein (UDP). The RDP, which includes all the non-protein N and some true protein in the diet, is broken down in the rumen and then resynthesised into microbial protein at a rate determined by the energy metabolism of the rumen microbes. Two forms of dietary protein escape into the abomasum: namely UDP and microbial protein.

There is a fairly constant relationship between the amount of microbial protein produced and the availability of ME. If there is more RDP than available energy, the excess N that is already converted into ammonia is not recaptured by the microbes. This is absorbed through the rumen wall and converted into urea in the liver. Much of this blood urea is excreted in the urine and therefore wasted, although some is recycled back into the rumen as salivary urea.

The best way to ensure that feed protein is efficiently used by calves is to supply it in the form of UDP; that is, feed protein escaping rumen fermentation that passes directly to the abomasum for acid digestion.

The requirements for amino acids depend on the rate at which the calf is producing new tissue – its growth rate. As growth rate increases so do its requirements for RDP and UDP (in g/day) and its total dietary protein content (as % DM). These are shown in Table 4.1 for calves growing at 0.5 and 1.0 kg/day.

These protein requirements were calculated for a crossbred Friesian steer calf. Bull calves and calves from larger European beef breeds require an additional 10–15% UDP. The table also converts these RDP and UDP values to more practical units, namely the minimum crude protein of the diet and the optimal degradability of the protein (calculated as the percentage of RDP in the total crude protein). Younger, lighter calves require higher dietary crude protein levels and need more of their protein as UDP (they have lower optimum protein degradabilities).

There is also evidence suggesting that the degradability of dietary protein can influence the composition of live weight gain. For example, if calves consume rations providing adequate energy and total crude protein, but UDP intakes are below recommended levels, growth rate may not be reduced but more of the live weight gain would be as fatty tissue and less as muscle. This has important implications for growing dairy heifer replacements because excess fat in the developing udder can reduce the potential for that udder to produce milk in later life. Early muscle growth is important for dairy beef calves to achieve target live weights for slaughter at set criteria of carcass fatness.

The supply of UDP, as opposed to RDP, in the diets of milk-fed calves is not important because liquid feeds already bypass the rumen digestion, through the oesophageal groove (see Chapter 3), and so supply the necessary UDP for growth and development. In fact, rumen development requires rumen digestion and so a supply of RDP in solid feeds will be beneficial to milk-fed calves. Because all feeds must enter the rumen in weaned calves, the type of feed protein is important. Most vegetable proteins are highly degraded, while animal proteins are more protected against rumen degradation. Extra processing – for example heating or the addition of chemicals such as formaldehyde – can reduce the degradability of feed proteins.

Increasing the supply of energy to the weaned calf will increase the amount of RDP that the rumen microbes can resynthesise into microbial protein. In other words, the balance of RDP and UDP is not constant for any type of feed but will vary depending on the other ingredients in the total ration.

Feeds high in UDP are processed protein meals such as cottonseed or canola meal. Feeds with high RDP/ME balances are fresh and conserved pastures, protein meals and urea. Feeds with low RDP/ME balances include cereal grains, maize silage and cereal straws. When formulating a ration for weaned calves, it is important to balance the feeds for both protein and energy.

4.4 Fibre

Highly fibrous feeds stimulate saliva production during chewing and rumination. The saliva provides urea and minerals, such as sodium bicarbonate, that help maintain normal rumen microbial growth and development.

Fine grinding of feeds changes the physical nature of the fibre, but not its chemical analyses, and this can reduce its effect on rumen development. Mixing roughage with concentrates to assure consumption of both feeds without separation may require the reduction of particle size to the point that the physical abrasion (or ‘scratch factor’) in the roughage has lost its beneficial effects. The initial introduction of solid feeds should contain from 10 to 20% of the DM as roughage, with the particle size maintained as large as possible.

Dietary fibre can be quantified in various ways. Traditionally it was described in terms of crude fibre (CF), but this is being replaced by two terms: namely acid detergent fibre (ADF) and neutral detergent fibre (NDF). ADF is made up of the cellulose and lignin in the feed, while NDF also includes an additional fibre source, namely hemicellulose. NDF then quantifies the cell walls in the forage and is discussed in Chapter 10.

4.5 Minerals and vitamins

The two minerals of most importance to growing calves are **calcium** (Ca) and **phosphorus** (P) because both are required for bone development. These minerals also have other, more dynamic functions such as in muscle function (Ca) and energy metabolism (P).

One of the earliest signs of deficiencies of these major minerals is poor growth and poor appetite. As with most mineral and vitamin deficiencies, these early signs are not

Table 4.2. Requirements of weaned calves for major minerals at different live weights and for different growth rates (prepared by Webster 1984)

Mineral	Growth rate (kg/day)	Live weight (kg)			
		100		200	
		g/day	% in DM	g/day	% in DM
Calcium	0.5	12	0.42	14	0.30
	1.0	21	0.75	24	0.50
Phosphorus	0.5	6	0.20	8	0.20
	1.0	11	0.40	13	0.30
Magnesium	0.5	3	0.10	4.8	0.10
	1.0	4.2	0.20	6	0.15

very specific; the calves simply do not appear to be doing well. This can also apply to calves suffering from parasitism or infectious diseases but, once these are eliminated, calves must be provided with the deficient nutrient before they respond. If they do not respond, then something else is wrong.

Calves do not possess what is often called 'nutritional wisdom'; they have no innate ability to select feeds to satisfy any particular nutrient craving. The only possible exception is sodium – cattle can sense the presence of sodium in rock salt or in drinking water at incredibly low concentrations. Despite what producers may be told, the intake by cattle or calves of mineral blocks bears little relationship to their mineral requirements. Deficiencies of calcium and phosphorus in milk-fed calves are rare. However, they can occur after weaning if calves are fed unbalanced diets.

The other major minerals for calves are **magnesium, sodium** and **potassium**. Deficiencies are unlikely except as complications of diseases that lead to scouring. They should be included in electrolyte solutions given as part of the treatment for scours. Table 4.2 shows the requirements of growing calves for major minerals, as summarised by Webster (1984), both as requirements in g/day and as minimum dietary DM concentrations.

Higher levels of dietary minerals are required to achieve growth rates of 1.0 kg/day compared with 0.5 kg/day. Most standard feeding tables have mineral concentrations of the available feeds and from these it is possible to determine whether additional mineral premixes should be included in calf diets.

Calf rearers can generally assume that purchased milk replacers and concentrate mixes contain the correct level of minerals for normal calf development. It is rare for problems to arise through mineral deficiency or imbalance, but as higher animal performance is sought by calf rearers, certain minerals may become limiting. One example of such an imbalance could arise from the low calcium content of most cereal grains when fed in large amounts to maximise growth rates.

If calves are grown for veal, it is important to monitor the level of **iron** in the diet. Calves are born with low reserves of iron and the amount of iron is very low in whole milk. Additional iron supplements can increase both blood haemoglobin levels and growth rates in young calves.

The colour of meat in calves is largely influenced by its iron status. White veal is very pale because the calf becomes anaemic and lacks those meat and blood pigments that are high in iron. Pink veal allows for higher intakes of iron through concentrate feeding, but they should be kept low enough to ensure pink rather than red coloured meat. White veal is normally produced on a diet entirely of whole milk or milk replacer, although veal producers are now being pressured to include solid feeds in white veal diets.

Calves are born with very low reserves of **vitamins A, D and E** and hence are very dependent on colostrum to supply these vitamins. Most milk replacers have enhanced levels of vitamins because of their importance to calf health. The milk-fed calf is also unable to synthesise its requirements for the complex of B vitamins and these are normally added to milk replacers. Once the calf has a functioning rumen, it is capable of supplying its own B vitamins, and these are not normally added to concentrate mixes.

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