NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Realistic Rations - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/livestock/dairy-cattle/feed/publications/realistic-rations

Updated versions of this document can also be found at the above web address.

Understanding the dairy cow & her feed

Aims of this section

Feeding a dairy cow means more than presenting adequate food. The dairy cow has special requirements which her diet has to provide. Today's dairy farmers need to be aware of these requirements; when you are determining how your cows will be fed you should know what feeds are the best to use.

Completing this section will give you a greater knowledge of:

- how a cow breaks down feed for her body to use
- the importance of the rumen and its bacteria
- how to determine the value of a feed
- the different components measured in feed and what they mean
- how much a cow can eat
- what nutrients are needed by the cow
- how much of these nutrients is required by the cow for health, growth, pregnancy and milk production
- what feeds supply different nutrients
- practical tips for getting good results when feeds are sent away to be analysed.

Knowledge level required

To understand this section you need a practical knowledge of dairy cows and dairy farming. Reading the DairyLink manual *Conserving Feed* will give you some valuable background on the types and values of different silages and hays.

Information in the DairyLink manuals *Establishing Pastures* and *Managing Pastures* provides details of pasture costs and grazing management, both of which affect ration formulation.

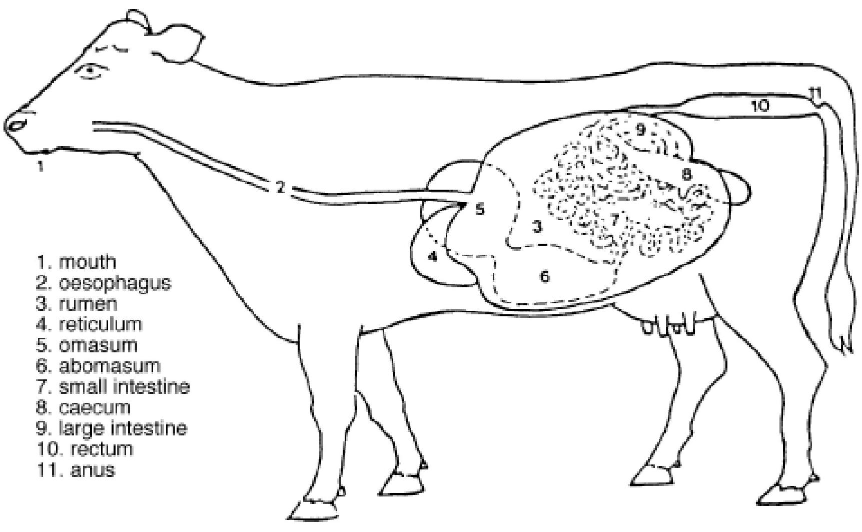
How do cows use feed?

What is the cow's digestive system and how does it work?

Anatomy of the digestive system

The digestive system of ruminants (for example, cows, sheep and deer) differs from that of other animals because it has a

Figure 1.1: The cow's digestive system



four chambered stomach, not a single stomach. Figure 1.1 shows the cow's digestive system.

The digestive system starts at the mouth and ends at the anus. It is a continuous tube that has special functions along its length, and has a number of accessories, called glands, which help it work.

The digestive system's main functions are intake of food, breakdown of food into compounds which can be used by the body (digestion), transport of the compounds into the body (absorption) and elimination of waste.

The **mouth** of the cow is well designed for ripping pasture and grinding feed.

The **tongue** is extremely movable and has a covering of sharp, backward-pointing projections that help direct food towards the throat.

The **teeth** are designed for grinding and chopping. There are no upper front teeth (incisors)—instead, there is a dental plate which the lower incisors come into contact with.

The dental pattern for an adult cow is:

	Upper Jaw		**Lower Jaw**	
	Left	Right	Left	Right
Incisors	0	0	4	4
Canine	0	0	0	0
Premolars	3	3	3	3
Molars	3	3	3	3

There are six glands which produce saliva to aid the initial digestion of food (**salivary glands**). Two glands are situated below the ear (parotid), two near the back of the throat (mandibular) and two under the tongue (sublingual). These glands produce 70–180 litres of alkaline (pH 7.7–8.7) saliva each day. The volume of saliva produced depends on the diet.

The **pharynx** is the cavity between the mouth and the opening of the **oesophagus**. The oesophagus is the muscular tube from the pharynx to the stomach. Food can be moved either up or down the oesophagus by muscular contractions.

The **stomach** has four chambers. It fills the left-hand side of the abdomen, pushing the rest of the digestive tract to the right-hand side.

The four parts of the stomach are the **rumen** ('paunch'), **reticulum** ('honeycomb'), **omasum** ('bible') and **abomasum** (which is similar to the single stomach of non-ruminants). The rumen contains microbes which aid digestion of food.

In the young ruminant, a groove formed by two muscular folds runs along the top wall of the rumen area, connecting the oesophagus with the abomasum. This **reticular** or **oesophageal groove** is stimulated by the action of suckling and allows colostrum and milk to bypass the immature rumen. If the calf has access to hay and grain from the first week of life, the rumen-reticulum begins to function and should be fully functional and able to digest forages by the third or fourth week of life.

The **small intestine** leaves the abomasum and sits in the right-hand side of the abdomen. It is about 40 metres long and has three parts, the **duodenum**, **jejunum** and **ileum**. The **gall bladder** and **pancreas** are two glands along this part of the digestive tract; they provide secretions that help digestion in this section of the gut.

The **large intestine** sits in the upper right part of the abdomen. It consist of the **caecum** (similar to our appendix), **colon** and **rectum**. The caecum and colon, similar to the rumen, contain microbes that aid digestion.

How digestion works

Food consists of chemical compounds (such as proteins, starch and fibre) which cannot be used by the animal unless they are broken down into smaller components.

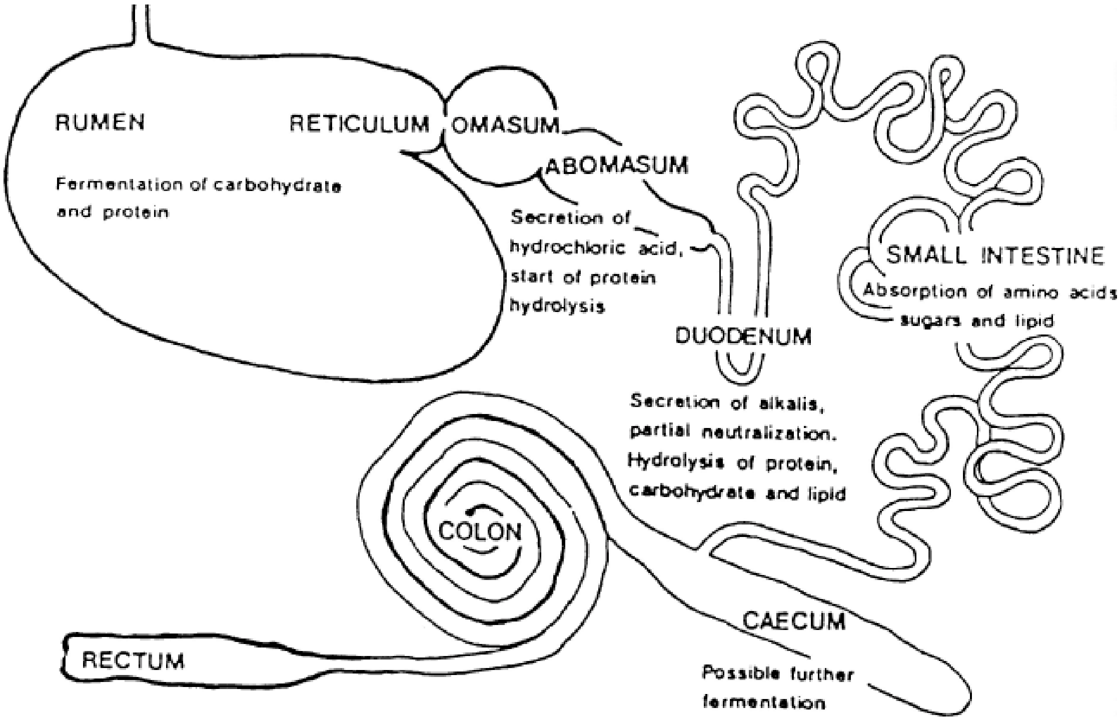


Figure 1.2: How the cow digests food

These components are transported into the blood system and circulated throughout the body to be used by the different organs. In the organs, the components can be rebuilt into other compounds which the body can use. For example, compounds reaching the udder by the blood can be made into milk fat and milk protein. Figure 1.2 shows how the cow digests food.

This process of breaking down and rebuilding components is known as **metabolism**.

Enzymes are special proteins which help drive the chemical reactions involved in breaking down or rebuilding compounds. In single-stomach animals, such as dogs and cats, glands associated with the digestive system are the main source of the enzymes needed for digestion. In ruminants, enzymes released by microbes in the rumen digest about 65% of food.

How the cow's stomach digests food

Ruminants digest feeds primarily by fermentation by microbes in the rumen. These microbes have specific functions. One group (anaerobic bacteria, protozoa and fungi) break down carbohydrates in the diet. Another group (anaerobic bacteria and some fungi) break down the structural fibre of plants. There is a working relationship between the microbes: the fungi might start the fermentation process by attacking the plant cell walls, then other microbes break down the products released into smaller compounds which are absorbed by the cow or else are used by the microbes for their own growth.

The **rumen-reticulum** first receives the food entering the stomach complex. It is similar to a large fermentation vessel. The feedstuffs and the rumen microbes are continually mixed by muscular contractions of the wall of the rumen. The feed may be digested by enzymes produced by microbes or present in the saliva. Because many compounds produced during digestion are acid, the saliva helps buffer the rumen, maintaining the 'neutral' (pH 5.8–6.8) environment needed by the microbes. Some of the digested product (ammonia and volatile fatty acids) may be absorbed through the rumen wall into the blood. Gas (methane and carbon dioxide) may be produced during the digestion process and is belched out of the rumen.Energy, in the form of the molecule Adenosine Triphosphate (ATP), is taken up by the microbes for their growth.

Fibrous feed is regurgitated up the oesophagus to the mouth to be more thoroughly chewed and reduced in size before it is reswallowed; this is known as rumination or 'chewing the cud'. On a grass-based diet, twice the amount of dry feed material as was originally eaten passes through the cycle of rumination. The small particles of food then pass on to the reticulum and omasum. The valve between the reticulum and omasum keeps feed particles in the rumen until they are less than 1–2 mm in size.

The **omasum** absorbs 30–60% of water leaving the rumen-reticulum. The water contains products of digestion such as volatile fatty acids and minerals.

The **abomasum** is the equivalent of a non-ruminant's stomach. It has acid secretions that break down escaped rumen microbes and other compounds so that they are ready for digestion by the small intestine.

The **small intestine** digests and absorbs any fat or protein not digested by the rumen, as well as some of the soluble carbohydrate. Escaped rumen microbes are digested and their protein absorbed.

The indigestible products pass into the **large intestine**, where they undergo a second fermentation. Only 5–10% of the total digestion of feed occurs in the large intestine. It contains microbes that attack the insoluble carbohydrates and starch. Any volatile fatty acids produced (together with minerals and water) are absorbed. The microbes from the large intestine pass out with the undigested material in the faeces.

Feeding the rumen

The fibrous pasture and forages in a cow's diet must be digested through the activity of microbes. Without these microbes, the cow will die. Feeding too much grain can cause certain microbes to break down the carbohydrates in the grain, in preference to microbes which break down fibre. If the excessive amounts of acid produced from the breakdown of the grain cannot be neutralised by the cow's high pH saliva, the pH of the rumen decreases (becomes acidic). Certain microbes that are not suited to the acidic conditions may be killed. Damage can occur to parts of the rumen wall—especially the folds, which are important for absorbing compounds into the blood. Carbon dioxide gas can build up in the top of the rumen and can 'bloat' the rumen unless it is able to be 'burped'. At one extreme the end result is poor digestion of fibre-based feeds; at the other extreme the cow becomes sick and dies.

It is important to make sure the rumen is functioning properly when you start feeding a cow. To do this, you must understand how to get a proper balance of feed types in the ration.

How do we measure feed value?

The value of a feed and its usefulness to an animal are determined by what it contains and how much of it is eaten. The **nutritive value** of a feed is determined by the following:

- what is in the feed
- how it is digested by the rumen microbes and by the cow
- the physiological state of the cow.

Feed analysis

Feed analysis determines what is present

Table 1.1: Brewers' grain—proximate analysis

Component	Value
Dry matter (DM)	26.0%
Nitrogen	3.2%
Crude protein	19.8%
Acid detergent fibre	30.1%
Digestible dry matter	67.1%
Metabolisable energy	10.1 MJ/kg DM

in a feed—it measures only one part of a feed's nutritive value. Feed analysis is done with special equipment in a laboratory, although in the future it will be possible to do analyses on-farm.

Proximate analysis is the chemical analysis of feed to assess its nutrient content. Table 1.1 shows the results of a proximate analysis of a feed.

Dry matter, **metabolisable energy**, **crude protein** and **digestibility** are some of the components determined. What do these components mean? In this section, the following components which make up the proximate analysis of feed will be explained.

Dry Matter (DM)

- Dry matter intake (DMI)

Energy

- Gross Energy (GE)
- Digestible Energy (DE)
- Metabolisable Energy (ME)
- Net Energy System (NEl, NEm, NEp)
- Total Digestible Nutrients (TDN)

Protein

- Non protein nitrogen (NPN)
- Rumen Degradable Protein (RDP)
- Undegraded Dietary Protein (UDP)
- Bypass Protein
- Protein degradability (Pdg%)

Carbohydrates

- Fibre
  - —Neutral Detergent Fibre (NDF)
  - —Acid Detergent Fibre (ADF)
  - —Lignin
  - —Crude Fibre (CF)
- Non-structural carbohydrates (NSC)
- Non-fibre carbohydrates (NFC)

Fats and oils

- Crude fat

Digestibility

- DMD

Dry matter

Dry matter (DM) is the feed material remaining after a feed sample is dried so that all moisture is removed. Water, which is present in all feeds, does not provide any nutrients or energy needed by the cow. Dry matter is used as a measure of the quantity of feed that is fed to a cow.

Dry matter intake is the quantity of moisture-free feed consumed by a cow in a 24-hour period.

Some nutrients in a feed (such as crude protein, neutral detergent fibre, acid detergent fibre and minerals) are calculated as a percentage of the ration's dry matter; others (such as energy) are calculated as a value per kilogram of dry matter.

The values of different feeds can be

compared by relating them to their dry matter content. **It is important to know the dry matter content of feeds when you are changing from one feed to another in a ration.**

There are a number of laboratory methods for measuring dry matter in feeds. A practical way of using a microwave oven to determine dry matter percentage is described in Appendix 1 at the end of this manual.

Units of measurement

The **dry matter percentage** is the dry matter content of a sample of feed, expressed as a percentage of the wet sample. It is based on the difference in weight after the sample is dried. Appendix 1 explains how to calculate dry matter percentage.

The amount of water present in a feed is the inverse of the dry matter percentage. So if a feed has a dry matter percentage of 20%, then 80% of the feed is water (100 - 20%).

Feeds may be described on a fresh, wet weight (**'as fed'**) basis rather than a dry matter basis.When you are determining a ration for a herd it is important to know the **as fed** weight, as this is important for weighing feed before mixing. To convert from a dry matter percentage to an **as fed** value, multiply the amount of feed on a dry matter basis by the inverse of the dry matter percentage.

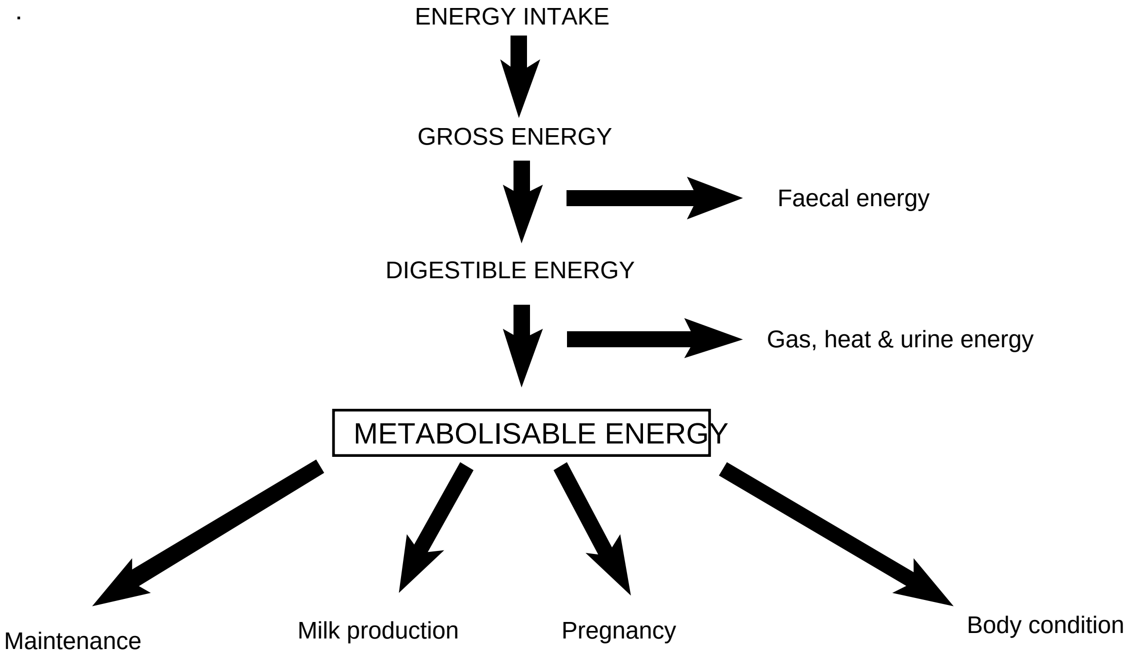
For example, if 100 kg DM of a feed is to be added to a ration mix, and the feed has a **dry matter percentage** of 50%, then the total weight of the feed to be added is 100 kg × 100/50 or 200 kg on an **as fed** basis.

Energy

Energy is needed for the normal body functions of the cow. It is the most important nutrient for driving milk production. Energy is also needed for walking, putting on body condition and nourishing the developing foetus if the cow is pregnant. Cows get their energy from the digestion of feed.

The total energy in a feed is called its **gross energy**. Not all of this energy is available to the cow—some of it will be lost in the faeces. The remaining energy is called **digestible energy**—the portion of

Figure 1.3: Metabolisable energy is the energy available for use by the cow (adapted from Agriculture Victoria, 1994)



energy from the feed which is available for digestion.

During the process of digestion, energy is lost in the manufacture of waste products which leave the body in the urine or as gas belched from the rumen (methane), and through excess heat production by the cow. The remaining energy is now available to the cow for body maintenance, milk production, pregnancy and body conditioning. This energy is called **metabolisable energy** (see Figure 1.3).

Feeds may have similar gross energy contents but may vary in the total energy available for milk production and body maintenance. Only the energy available for use by the cow (metabolisable energy) is determined for different feeds. This energy is expressed as **megajoules of metabolisable energy per kilogram of dry matter** or **MJME/kg DM**.

The higher the MJME in a feed, the greater the energy the feed provides to the animal.

Units of measurement

The basic unit of energy is a joule, which equals 0.239 calories. One megajoule is one million joules.

The **metabolisable energy system** for measuring a cow's energy needs is used in Australia. The results from any Australian Feed Analysis laboratory express the metabolisable energy of the feed as **MJME/kg DM**.

In the USA, the **net energy system** is used. In the net energy system, there are three components: net energy for maintenance (NEm), net energy for lactation (NEl) and net energy for growth and weight gain (NEg). Net energy is equivalent to metabolisable energy minus the energy used in the process of digestion and metabolism but includes the energy in the feed used for maintenance and production.

If you are reading an American publication, the NEl value can be converted to a metabolisable energy value by dividing it by 0.62. If a total NE value is given in megacalories, then this figure can be converted to metabolisable energy in MJME by multiplying the value by 6.8.

If the publication expresses the results in megacalories instead of megajoules, convert the result to megajoules by dividing by 4.184.

Another term used in American publications is **total digestible nutrients** or TDN. TDN is a feed value calculated from the total analysis of a feed. It is commonly used to represent the digestible energy in a diet and is expressed as a percentage of gross energy. TDN can be converted to a metabolisable energy value by multiplying the value by 0.1476.

Protein

Feed contains the element **nitrogen**, which is normally found in the protein part of the feed. **Protein** is usually 16% nitrogen. Feed can also contain nitrogens from other sources; these are **non-protein nitrogens (NPNs)**, such as urea.

The percentage of **crude protein** in a feed is calculated by multiplying the nitrogen content by 6.25 (because protein contains 16% or 16 in 100 parts nitrogen). This value contains both true protein and non-protein nitrogen sources.

The nature of a protein and its passage through the rumen (see Figure 1.4) can affect the following:

- the amount of protein digested and absorbed in the rumen
- the amount of protein that passes through the rumen for digestion and absorption in the small intestine.

Most protein entering the rumen can be broken down by microbes if it is in the rumen for long enough. A small amount of protein is **indigestible** by both microbial

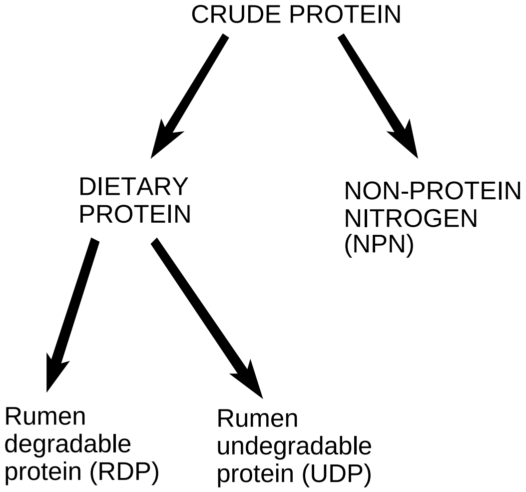


Figure 1.4: The components of crude protein (adapted from Agriculture Victoria, 1994)

and animal enzymes and will pass intact from the animal. No part of this protein will be absorbed or used in metabolism.

Protein entering the rumen is broken down by the microbes into amino acids. Most amino acids are further broken down to form **ammonia**, which is used by the microbes to produce their own protein for their reproduction and growth. Protein which is broken down in the rumen is **Rumen Degradable Protein (RDP)**.

Non-protein nitrogen is 100% degradable in the rumen. The excess ammonia from NPN and protein breakdown is absorbed through the rumen wall into the blood and travels to the liver to be detoxified by the formation of **urea**. Urea is excreted from the body in the urine.

Some microbes will pass out of the rumen into the abomasum. The proteins they contain are digested and absorbed by the cow in the small intestine. Microbial protein is the major source of protein for the cow.

Protein which passes through the rumen without being attacked by the microbes will pass into the small intestine to be digested and absorbed. This protein, called **Undegraded Dietary Protein (UDP)**, is not modified from its original state in the feedstuff. The amino acids it contains are released to the cow when the protein is digested in the small intestine.

In any feed, the protein will be a combination of RDP and UDP. Feeds with a high percentage of their protein as UDP are called **bypass proteins**. Slowing the passage of a feed through a rumen can affect its UDP percentage. The longer time a feed is in the rumen, the greater the chance of microbial attack and digestion.

Units of measurement

The feed test will normally show the protein content in the feed as crude protein. Crude protein is normally expressed as a percentage of a kilogram of dry matter content (**CP%**).

To calculate the total amount of crude protein as grams per kilogram of dry matter in the feed, simply multiply the percentage figure by 10.

For example, a feed can have 12% crude protein or 120 g/kg DM.

Sometimes the nitrogen value of a feed is given instead of a crude protein percentage. To convert the nitrogen value to a crude protein percentage, multiply the nitrogen value by 6.25. Remember that not all nitrogen will be part of protein; some of the nitrogen might be non-protein nitrogen such as urea. The nitrogen from protein and that from urea are not measured separately when a feed sample is analysed.

The protein degradability (Pdg%) is not given on a feed test result. The test used to determine this value is very expensive (about $1000) and is usually requested by feed companies when evaluating one of their products. However, you can find protein degradability percentages for a number of feeds in the literature (NRC, 1989).

The RDP value is often given as a percentage of the total crude protein. For example, the protein in a cereal grain may be 90% degraded in the rumen.

The feed requirements for RDP and UDP are often expressed as grams per kg DM. If a feed has a CP of 12% or 120 g/kg DM and an RDP of 90%, every kilogram of feed dry matter will contain 120 × 90/100g or 108 g of RDP.

Carbohydrates

The components of the feed that do not contain nitrogen (and so are not included in the crude protein determination), and all fibre components, are the **carbohydrates**. Carbohydrates make up about 75% of a plant's dry matter.

Fibre

Fibre provides the structural support for plants and cell walls. Feeds high in fibre are called roughages or forages. There are a number of measures of a feed's fibre content.

Neutral detergent fibre (NDF) is a measurement of the amount of plant cell wall or 'fibre' in forages. When a forage is boiled in a detergent with neutral (pH 7) detergent, all the contents of the cell dissolves except for the cell wall or NDF.

NDF contains carbohydrates (cellulose and hemicellulose) that are partly digested by the rumen bacteria but are not digested by the cow's intestines.

Acid detergent fibre (ADF) is the residue of lignin and cellulose remaining when the plant cell wall is treated with an acidic detergent solution. ADF is a useful measurement of the minimum fibre level in a ration, and is used to help calculate the energy value of a forage.

Lignin is the least digestible portion of the plant. It binds together the other carbohydrates in the plant and gives the plant rigidity.

Units of measurement

The fibre content in a feed will commonly be expressed as ADF, because this value is used by the laboratory in the calculation of energy. Some laboratories will provide the NDF value of the feed. Lignin can be measured in the feed, but it is not as useful for balancing rations as ADF and NDF.

Some publications use the term **crude fibre** (**CF**). Crude fibre includes the lignin and most of the cellulose in the feed. To get an approximation of CF, divide the ADF value by 1.15.

Soluble carbohydrates

Non-structural carbohydrates (NSC) are the carbohydrates that are not part of the plant cell wall (NDF). They are present in the cell contents. NSC are also called **non-fibre carbohydrates** or **NFC.**

NSC include **soluble sugars**, **starches** and **pectins**. Sugars are an instant energy source for the rumen microbes. Starches and pectins are storage carbohydrates that are fermented more slowly than sugars. NSC are more completely and rapidly digested in the rumen than the NDF carbohydrates. They can also be digested in the cow's intestine. The ration should contain 30–40% NSC in its total dry matter content.

Units of measurement

Direct measures of non-structural carbohydrates are not carried out in normal feed analysis. NSC is usually calculated by subtracting all the other components in the feed from 100. These components are fibre (NDF or CF), crude protein (CP), fat and oil (ether extract or EE), water content (100 - DM%) and mineral content (ash). Ash is the portion of feed remaining after it has been combusted at 650°C; it is the inorganic or mineral part of the feed.

In other words, the percentage of NSC in a feed can be calculated by the following equation:

NSC = 100 – (CP + CF + ether extract + ash + water content)

where all components are expressed in grams.

Fats and oils

Fats and oils are sources of energy. They have a similar structure to carbohydrates, except that they contain three fatty acid chains. For this reason they are called **triglycerides**. During breakdown (oxidation), they liberate 2.5 times more energy than carbohydrates of the same weight.

Units of measurement

The **crude fat** of a feed is estimated by the ether extract method. This method determines all the components in the feed that are soluble in ether—all the fats and oils as well as gums, resins and waxes. Ether extraction is not usually done in the feed analysis laboratory unless it is requested. For this reason, the true metabolisable energy of a feed may be higher than that reported from feed analysis if the feed contains fats or oils (for example, oilseed meal).

Digestibility

The organic part of the feed consists of everything except the mineral component (ash). The organic matter contains the energy of the feed, and there is a direct relationship between feed organic matter and gross energy. A proportion of the organic matter of the feed is indigestible—it contains lignin and some cellulose.

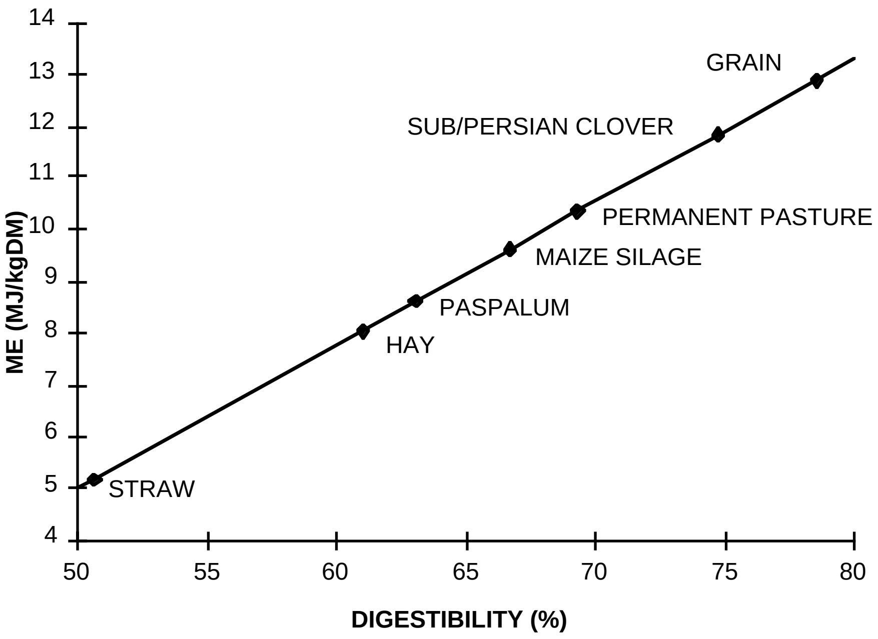
The **digestibility** of a feed is the proportion that can be digested by an animal. Digestibility is a guide to the energy value of a feed. It is commonly measured as a percentage (%).

Dry matter digestibility (DMD)

$$= \frac{\text{feed DM} - \text{faeces DM}}{\text{feed DM}} \times 100\%$$

As grasses mature, the organic matter content becomes more indigestible because the lignin content increases. For this reason, cows obtain greater energy from younger grasses; there is more feed

Figure 1.5: The relationship between digestibility and metabolisable energy (after MAFF, 1984)



available for digestion for every unit of weight of the plant.

The digestible organic matter in the dry matter portion of a plant (DOMD) gives information about the stage of growth of a plant and can be used to predict the energy the plant can supply (see Figure 1.5). This figure can be given as a percentage.

How much feed can a cow eat?

An important constraint of any dairy cow ration is how much the cow can eat. If you formulate a ration to supply the nutrients for body maintenance, walking, pregnancy and milk yield you must be able to supply it in amounts that the cow can eat.

A number of factors can affect a cow's dry matter intake.

Cow factors

- size and age
- physiological state
- genetics
- disease
- social interaction
- heat stress

Feed factors

- digestibility
- nutrient supply
- palatability

Physical factors

- ability to harvest pasture
- grazing time
- intake per bite
- access to feed

We will consider these factors in greater detail.

Cow factors

Size and age

The maintenance requirement of a cow is determined by her age, live weight and body surface area. A young heifer will eat more than an adult cow as a percentage of her body weight. A heifer will eat the equivalent of 2.3% of her body weight daily, and an adult dry cow will eat the equivalent of 1.5%. As an example, a 300 kg heifer can eat up to 7 kg dry matter. An adult dry cow weighing 470 kg will eat a similar amount.

The size of the rumen and its ability to expand are limited by the size of the body cavity where the rumen is situated. Distension of the rumen (**'gut fill'**) depends on the rate of breakdown of feed roughage and the flow of small particles from the rumen. Fat cows can have lower intakes because of the effect of fat deposits in the rumen and because they have lower energy requirements.

Physiological state

Milk production and stage of lactation can drive a cow's intake. Before a cow calves, her intake is reduced because of the physical restriction on the size of the rumen by the developing foetus and because of the hormonal changes associated with pregnancy.

After a cow calves, milk production begins; it reaches a peak yield at about 5–7 weeks after calving. The cow's metabolism has to adapt to this demand on her body reserves; her intake is initially depressed, but it gradually increases until she reaches full appetite at 8–20 weeks after calving.

This delay in reaching full appetite while the cow is producing peak yield means that the cow is in a **negative energy balance** for this period. She cannot eat enough to supply the nutrients needed for body maintenance, milk production and fertility. Weight loss usually occurs after calving.

The period between peak yield and full appetite can be shortened if the cow's rumen is encouraged to expand before calving. Medium quality forage, at least 11 mm in length, can provide the ‘scratch factor’ needed to stimulate rumen capacity. The cereal component of the lactating diet, **without the mineral mixes or buffers**, can be fed in small amounts to the cow for a month before calving to adapt the rumen microbes to the new diet.

Making changes to the early lactation diet and calving your cows in good condition will benefit the early lactation cow. These factors will be discussed later.

The intake of a lactating cow can be 30–60% greater than that of a non-lactating cow. There are numerous ways of predicting how much a cow will eat, but they are not as practical as an on-farm method. One simple **rule of thumb** for predicting dry matter intake is that a lactating cow will eat 2.5% of her live weight if given low quality forage, 3% of live weight if given a medium to good quality diet and 3.5% of live weight if given a high quality diet. Intakes as high as 4%, 4.5% and 5% of live weight can occur on well balanced rations, especially in Jersey cattle.

Another quick **rule of thumb** for determining the intake of a lactating cow requires you to know both her live weight and milk production. Her dry matter intake will be about (2.2 × live weight + 20 × daily milk production in litres) /100.

Example: What is the dry matter intake of a 500 kg cow producing 20 litres of milk a day?

$$\begin{aligned} \text{Dry matter intake} &= (2.2 \times 500 + 20 \times 20)/100 \\ &= (1100 + 400)/100 \\ &= 1500/100 \\ &= 15 \text{ kg DM.} \end{aligned}$$

Genetics

Dry matter intake can be influenced by the cow’s genetics. High breeding value cows can eat more. In these cows, a 5% increase in intake can result in a disproportionate increase in milk production (up to 30%).

Disease

A drop in appetite is a common sign of many diseases. The first sign of disease can be decreased in milk production, because the cow has reduced her feed intake.

Decreased intake can be caused by:

- metabolic changes in the cow as a result of disease (for example, milk fever or low blood calcium)
- physical changes in the rumen stimulating gut fill (for example, bloat)
- tumours and wounds in the mouth, pharynx or oesophagus
- diseases of the feet that physically restrict the ability of the cow to graze.

Social interaction

Cows are very social animals and have an established hierarchy or ‘pecking order’ within the herd. They form social groups, which may be family groups or their heifer group. The introduction of new animals to a herd can interfere with this structure until the hierarchy is re-established. Normal grazing patterns can become disrupted, resulting in lower feed intakes.

Mating groups can also form, especially in seasonally calving herds or in large herds where there is a significant number of cows on heat. Increased walking activity and behavioural changes can result in decreased feed intakes.

Heifers are most affected when they are introduced to a dairy herd. Many heifers can calve when they are only 75% of their mature weight. Individual heifers are on the lowest rung of the pecking order, especially if they are small and can be bullied by the more dominant cows. Heifers are disadvantaged at feed bunks if space is limited or at grazing if pasture feed is limited. Heifers grazed in groups separate

Table 1.2: Relationship of dry matter intake (DMI) to temperature

Mean day temperature (EC)	Mean night temperature (EC)	% reduction in DMI
25ñ30	20ñ25	10
30ñ35	20ñ30	20
35ñ40	25ñ30	30

from the adult herd have both higher feed intakes and milk production.

Heat stress

Dairy cows originated from cool, temperature climates and prefer environmental temperatures less than 25°C. Dry matter intake declines as the ambient temperature increases, as table 1.2 shows.

Heat stress caused by high temperatures can be increased if:

- there is poor access to cool, clean water
- there is high humidity—this prevents evaporation of heat; cows can show heat stress at relatively low temperatures if the humidity is high
- stock have to walk long distances
- stock do not have shade.

Feed factors

Digestibility

Dry matter intake increases by up to 65–80% with increasing digestibility of feed. Highly digestible feeds such as young pastures have comparatively less structural fibre (lignin) and are digested rapidly, allowing fast passage through the rumen. Gut fill is slower. Feeds with low digestibility (such as very mature pastures) limit intake by slowing the digestion and rumen passage and by accelerating gut fill.

Nutrient supply

Dry matter intake can be affected by:

- the quantities of nutrients absorbed by the rumen and small intestine
- the proportions of the different nutrients absorbed
- the type and level of nutrients in the feed.

Amino acids, from the breakdown of protein, stimulate intake. Volatile fatty acids, from the breakdown of fibre, can inhibit intake.

If the nitrogen content of the diet (crude protein content) meets the needs of the rumen microbes, intake will increase with increasing digestibility, providing the products produced during digestion have no adverse effect on the rumen or the cow.

Example: Grain has high digestibility (about 80%), but too much grain can cause acid conditions in the rumen which affect the digestion of fibre and reduce total intake. In acid rumen conditions, there is less nitrogen made into microbial protein, leading to fewer amino acids passing into the small intestine, reducing intake. If bloat occurs from eating too much grain or from eating clovers or lucerne, the distension of the rumen is sensed as 'gut fill' and intake reduces.

If two feeds have the same digestibility, intake will increase with increasing nitrogen (protein) intake. Feeds with low digestibility usually have a low nitrogen content. Increasing nitrogen in the diet (but only up to 10–12% CP) will provide greater nitrogen to the rumen microbes, allowing greater microbial growth and a greater ability to digest fibre. Intake increases in response to the improved fibre digestion.

Example: White clover – ryegrass pasture and ryegrass pasture have the same high digestibility. The higher milk production seen on white clover

– ryegrass pastures occurs because cows on these pastures have a greater nitrogen intake, which stimulates more microbial activity and a higher intake of pasture than occurs in cows grazed on ryegrass alone.

Palatability

Palatability is the cow's immediate response to the feed. The sight, smell, touch and taste of a feed can affect whether a cow will eat or refuse a feed. The palatability of poor quality roughages has a greater influence on intake than the palatability of better quality forages.

Exposing a calf to a variety of different feeds can influence how it accepts them in later life. One practical way of doing this is to feed small amounts of the milkers' ration to heifers.

Physical factors

Ability to harvest pasture

The pasture intake of a cow can be defined by a number of physical factors:

- the time spent grazing (grazing time)
- the number of times the cow bites the pasture (rate of biting)
- the amount of pasture harvested at each bite (intake per bite).

The total daily intake of pasture can be calculated by multiplying the grazing time (in minutes) by the rate of biting (bites per minute) by the intake per bite (kilograms per bite).

Both the grazing time and the intake per bite can be influenced by farmer management. The rate of biting is an individual character of a cow.

Grazing time

When a cow is at pasture, she can be either eating, ruminating ('chewing her cud') or resting. Cows graze mainly during the day, but night-time grazing increases if the day temperature is hot and humid. The average time most cows can spend grazing is 7–8 hours. Another 8 hours may be spent ruminating.

Farm management practices can severely limit grazing time. Excessive time spent in the milking yard and walking to and from pasture at milking time, as well as poor access to water in the paddock (requiring the cows to seek out a water trough in another place) will reduce the amount of time available to the cow for grazing.

Intake per bite

The amount of pasture available can determine how much a cow will eat at each bite. A cow will eat her requirement in pasture if she is provided with twice the dry matter content of pasture she needs. Cows are selective grazers and will seek out the more digestible (and higher energy) pasture in the longer pasture. If the cow is offered less than this, she will still eat the pasture but to a lower height. Her intake of the shorter pasture will be less. She will also be unable to select pasture and will take in less digestible parts of the pasture as well.

Access to feed

Cows should be allowed sufficient access to feed. In a pasture, the presence of weeds, dead plant material and manure pats can hinder the cows' ability to graze.

At a feed bunk, there should be sufficient space for each cow to eat without competing with another cow. Access is very important if most of the cows' feed requirement is fed at the bunk. There should be at least 76 cm of feeding space for each cow. Headstalls or self-locking stalls can allow cows adequate access to the feed.

In herds feeding on partly or totally mixed rations, separating the herd into different lactation group can benefit feed intake. Early lactation cows should have unimpeded access to the bunk area, and there should be sufficient space for every cow. High-producing cows should be presented with 10% more feed than they require. For mid- to late lactation cows, space should be sufficient for only 50–75% of the group to be eating at any one time.

The feed bunk should be cleaned out regularly, especially if feed with high moisture content is fed. If these feeds are left, moulds can build up and make the feed unpalatable, even when new feed is added.

Cattle fed in feedlots or on feed pads have a higher intake and milk production than pasture-fed cattle. Feedlot rations have a higher dry matter content than pastures, but the fibre content is usually lower. Pastures with a high dry matter content also have a high fibre content, which limits feed intake (the digestibility is lower). The rate of eating is faster in the feedlot, because highly digestible feed is presented to the cow—it doesn't have to search for it in a pasture. Pasture-fed cattle have to walk longer distances when grazing and use more energy in this activity than feedlot cattle.

What nutrients does the cow need?

The nutrients needed by the cow (in descending importance) are water, energy, protein, fibre, macro minerals, micro minerals and trace elements and vitamins.

Water

This is the most important nutrient required.

As saliva, water serves as an important lubricant for swallowing and regurgitation. It is needed for the process of digestion and absorption.

A lactating dairy cow needs a lot of water. Her body is 70–75% water, and the milk she produces is over 85% water. Inadequate water will markedly reduce milk production.

Usually a large proportion of the cow's water intake is supplied by pasture. When you supplement the cow' diet with grain and hay, the need to supply extra water increases.

As the environmental temperature and the cow's milk yield increase, so does the water requirement. Table 1.3 overleaf shows the water intake of 600 kg Holstein cows at different temperatures and milk yields.

How much water do your cows need? Use table 1.3 as a guide. For example on a cool spring day (14°C), a 600 kg cow producing 30 litres a day would need 103 litres of water. This would be supplied by water in the feed and drinking water. On a warm day in spring (24°C), the same cow would need 133 litres of water from the feed and the trough.

Dry cows and heifers need less water. For each kilogram of dry matter eaten, dry cows and heifers need 5–7 litres of water, again depending on the environmental temperature. If a dry cow on a warm spring day was eating 10 kg dry matter of grain and hay, then she would need about 70 litres of drinking water at the trough.

In dry, hot weather the requirement for water increases.

Energy

Energy is the next important nutrient and is the chief limiting nutrient of most feeds (although it is not an actual substance like protein or minerals). When complex substances are broken down, energy is released and becomes available to the animal. Carbohydrates such as sugars and starches (non-structural carbohydrates) and cellulose, hemicellulose and lignin (structural carbohydrates or fibre) are the main energy sources in a cow's diet. Fats (and to a lesser extent, protein) also provide energy.

Table 1.3: Water intake of 600 kg Holstein cows at different temperatures and milk yields

Milk yield	Environmental temperature (EC)			
	I 17 to 10	11 to 15	16 to 20	21 to 25
10	78	81	92	105
20	88	92	104	119
30	99	103	116	133
40	109	113	128	147

From *The Nutrient Requirements of Livestock* 1980

The structural and non-structural carbohydrates are converted to **volatile fatty acids** in the rumen. **Acetic**, **propionic** and **butyric acids (acetate, propionate** and **butyrate)** are the main volatile fatty acids formed. The starches and pectens which escape the rumen are converted to glucose in the small intestine.

The proportion of volatile fatty acids produced depends on the original diet. If the diet mainly contains structural carbohydrates (forages such as pasture and hay), the cellulose-digesting bacteria will predominate and large quantities of acetate will be produced. **Acetate is the immediate precursor of milk fat**. A deficiency of acetate can result in low milk fat percentage.

If the diet contains a large proportion of non-structural carbohydrates that are rapidly fermentable in the rumen (such as cereal grains) different bacteria will be favoured and a higher proportion of propionate will be produced. **Propionate is converted in the liver to glucose. Glucose provides the energy for the production of lactose and synthesis of protein in milk**. Lactose secretion is the main determinant of milk yield. A deficiency of propionate can result in decreased milk yield and milk composition. **Glucose provides the energy needed for live weight gain.** If the cow has a deficiency of propionate she can start to mobilise her own body tissue and lose weight.

Butyrate, another volatile fatty acid produced in the rumen, is metabolised in the liver to **ketone bodies**, the source of energy for fatty acid synthesis, skeletal muscles and other body tissues. Ketone bodies are also produced when body fat is mobilised; they are used as an alternative energy source for the cow.

Fats are degraded in the rumen or, if in a protected form, pass to the intestine. Fats and oils are modified in the rumen into **saturated fat** and absorbed. They are either converted to a specific animal body fat (usually a triglyceride) or oxidised to a gas if they are used as an energy source. Every lactation a cow goes through the process of accumulating and oxidising her body fat.

If there is too much fat in a cow's diet, fibre particles become coated with fat, making the surfaces difficult for microbial attack. Large amounts of fats can:

- depress the digestion of forages
- reduce the total feed intake
- lower the acetate to propionate ratio
- reduce the availability of calcium
- reduce the production of microbial protein.

Cows can tolerate as much as 900 g of fat a day in their diet (or 5–7% of the ration's total dry matter).

Protected fats escape microbial digestion and can be used to overcome the problem of increased breakdown of fat in the rumen.

How much energy is needed by the cow?

The metabolisable energy in a feed has to be partitioned to the different body functions. In decreasing order of importance, energy will be partitioned to maintenance, activity, pregnancy and milk production. If the energy in the feed is insufficient for all body functions, milk production will be the first function affected.

Maintenance

How much energy does a cow need for her body maintenance? Table 1.4 shows the energy required daily for maintenance at different live weights.

Activity

Cows need energy for walking. If the topography of the dairy is flat, a cow will need an extra 1 MJ of ME for each kilometre walked. If the topography is hilly, more energy is used and a cow may need up to 5 MJ of ME per kilometre.

Pregnancy

What energy is required for a pregnant cow? The growing calf foetus is drawing all of its energy from its mother. In the last four months of pregnancy, the demands of the foetus must be allowed for. Table 1.5 shows the extra energy required by the cow for pregnancy.

Milk production

Energy is the most important nutrient determining **milk production** and **milk protein content**. The amount of energy needed depends on the number of litres produced and the composition of the milk (milk fat and protein content). Table 1.6 shows the amount of energy needed to produce a litre of milk of a number of different compositions.

Table 1.4: Energy needed for maintenance

Live weight (kg)	Energy required (MJ of ME)
350	40
400	45
450	49
500	54
550	59
600	63
650	68
700	73

Body condition

Cows gaining condition require extra energy. For each kg of weight gained, an extra 34 MJ of ME is needed.

When a cow loses condition, energy becomes available to the cow. For each kg of weight lost, 28 MJ of ME is released for the cow to use.

When we assess the condition of a cow, we use a system called ‘condition scoring’ (see later). In Australia, the scoring system we use ranges from 1–8 ‘condition scores’, which are based on the degree of fatness of the cow. For Holstein–Friesians, one condition score is equivalent to 42 kg live weight. For Jerseys, one condition score is about 26 kg live weight.

The energy needed for a Holstein–Friesian to gain one condition score is 42 × 34 MJ of ME or 1428 MJ of ME. This energy requirement is above that already needed for maintenance, lactation and pregnancy.

Rules of thumb

Is there another way of calculating cow energy requirements?

There are a number of **rules of thumb** for quickly estimating how much energy a

Table 1.5: Energy needed for pregnancy

	Month of pregnancy			
	6	7	8	9
Extra energy needed (MJ of ME per day)	7ñ8	10	14	19ñ20

cow needs. One rough guide is to use the maintenance requirement which is typical for the herd, multiply the average milk production by 5 MJ, and add the two figures together to get an estimate of the cow's energy requirement. If the average live weight of a Holstein–Friesian herd is 550 kg then (from table 1.4) the maintenance requirement is 59 MJ. If the average milk production is 15 litres, the energy requirement for milk production will be 15 × 5 MJ or 75 MJ. So the total requirement for the average cow will be 134 MJ. This figure is a quick guide only but it can be useful to help you assess if the energy in the ration is adequate.

Example: What is the energy requirement for a 550 kg Holstein-Friesian cow, in late lactation, producing 15 litres of 3.2% protein, 3.8% fat milk. The cow is 6 months pregnant. The dairy is about 2 km flat walk from the day paddocks. The night paddocks are close to the dairy.

Use Table 1.4 to find the maintenance requirement for a 550 cow: 59 MJ

Use Table 1.5 to find the energy needed for pregnancy: 8 MJ

Use Table 1.6 to find the energy needed for each litre of 3.2% protein and 3.8% fat milk (5.2 MJ) and multiply this value by the daily production of 15 litres: 78 MJ

Calculate the energy needed for walking 4 km per day (from the section on Activity, this will be about 1 MJ per kilometre on flat land): 4 MJ

Total energy needed: 149 MJ

How much energy is needed if the same cow is to gain 0.5 kg live weight a day?

Table 1.6: Energy needed to produce milk of various fat and protein compositions

	Milk protein %					
	2.6	2.8	3.0	3.2	3.4	3.6
Milk fat %	Energy needed for milk production MJME/day)					
3.0	4.5	4.5	4.6	4.7	4.8	4.8
3.2	4.6	4.7	4.7	4.8	4.9	5.0
3.4	4.7	4.8	4.9	4.9	5.0	5.1
3.6	4.9	4.9	5.0	5.1	5.1	5.2
3.8	5.0	5.1	5.1	5.2	5.3	5.3
4.0	5.1	5.2	5.3	5.3	5.4	5.5
4.2	5.3	5.3	5.4	5.5	5.5	5.6
4.4	5.4	5.5	5.5	5.6	5.7	5.7
4.6	5.5	5.6	5.7	5.7	5.8	5.9
4.8	5.6	5.7	5.8	5.9	5.9	6.0
5.0	5.8	5.8	5.9	6.0	6.1	6.1
5.2	5.9	6.0	6.0	6.1	6.2	6.3

From the section on Body Condition, for every kilogram of weight gain the cow requires 34 MJ of ME. So to gain 0.5 kg per day, the cow will need an extra 17 MJ per day.

Protein

Proteins are made up of **amino acids**. The cow needs 25 amino acids for body metabolism, growth, milk production and the development of the foetus. Of these amino acids, there are 10 which the cow cannot make. These are the **essential amino acids**, which must be supplied in the diet or can be released after the digestion of the rumen microbes (microbial protein) in the small intestine.

The essential amino acids are:

- methionine
- lysine
- histidine
- threonine
- phenylalanine
- tryptophan
- arginine
- branched chain amino acids

Methionine and lysine are considered the main limiting amino acids in cows for milk production.

Amino acids can come from two sources:

- rumen microbes that pass out of the rumen into the small intestine and are digested.
- dietary protein that escapes the rumen and is digested in the small intestine (UDP).

Rumen microbes use the ammonia and nitrogen released from either dietary protein broken down in the rumen (RDP) or from non-protein nitrogen sources such as urea to manufacture their own protein. RDP could be classified as the dietary protein needed by the rumen microbes, not the cow.

Feeds and microbes vary in their ability to supply the different essential amino acids. Some feeds are unbalanced in the essential amino acids they supply. These unbalanced protein feeds (such as corn gluten meal) are less efficient for the synthesis of milk protein than balanced protein sources (such as soybean meal). Rumen bacteria supply most of the essential amino acid methionine and rumen protozoa supply most of the lysine. The overall diet can preferentially encourage the growth of one species of microbe over another by providing the substrate preferred by one group of microbes.

Too much protein in the diet can cause excessive ammonia production in the rumen, especially if the energy level in the diet is inadequate. If this is the case, the rumen microbes don't have enough energy to convert the ammonia to protein. The ammonia is absorbed from the rumen and enters the bloodstream and travels to the liver. The liver converts the ammonia to urea for excretion into the urine. Energy is needed for this process. High blood ammonia levels is associated with reduced conception in cows (especially heifers).

If there is not enough protein in the diet or too much dietary energy compared with protein, microbial protein synthesis decreases, resulting in a decrease in the total amount of protein available to the cow. The excess energy is used for putting on body condition rather than for milk production.

If there is not enough energy in the diet, the dietary protein (especially UDP) can be used as an energy source, resulting in a poor milk response.

How much protein does a cow need?

The amount of crude protein a cow needs varies throughout lactation. The amount of protein required per energy unit in the diet is much higher for milk production than for maintenance.

A range of crude protein percentages is given below. The high range value is suitable for high-producing cows and those cows receiving significant amounts of supplements. The crude protein should contain 30–35% of UDP.

- In early lactation, the diet should contain 16–18 % crude protein. If the cow is producing over 16 litres a day, the crude protein percentage should be about 18%, with a proportion of the protein as UDP. According to Kellaway, the UDP requirement for cows producing over 16 litres per day is 93 g for each litre over 16 litres.

Example: How much UDP does a cow producing 30 litres in early lactation need?

The cow needs 93 × (30–16) g or 93 × 14 g of UDP or 1302 g.

- In mid-lactation, the diet should contain 14–16% crude protein.
- In late lactation, the diet should contain 12–14% crude protein.
- Dry cows should receive 10–12% crude protein.
- Springers may need 15% crude protein if they are receiving a special ration.

For some rations you will need more specific information on protein requirements. This is given in table 1.7 and 1.8.

Do cows need UDP?

The answer to this question depends on your farm management, the genetic potential of your cows, and the feed making up the rest of the cows' ration. Early lactation cows with a potential for high milk production will need UDP. In early lactation the cow's appetite is depressed and she may not be able to consume enough nutrients for her potential milk production. She will be 'milking off her back'—using her body energy reserves.

Table 1.7: Protein needed for maintenance

Live weight (kg)	Crude protein needed for maintenance (g/day)
450	400
500	430
550	460
600	490
650	520
700	540

If the ration is deficient in feeds providing sufficient energy for maintenance, growth and reproduction, especially in early lactation, the protein supplement will be used by the cow to make up this shortfall in energy. The minimum UDP and RDP requirements for cows at different live weight and milk production are shown in table 1.9. The assumptions used to calculate these figures are:

- 8–10 g of microbial protein is produced for every MJ of ME consumed
- the 'type' cow used in the table is not pregnant and is producing milk with an

Table 1.8: Protein needed for milk production

Crude protein (g) needed for each litre of milk		
4.5% BF 3.6% P	4.0% BF 3.4% P	3.5% BF 3.2% P
92	87	82

BF = butterfat

P = protein

average composition of 4.0% BF and 3.2% P

Fibre

The source of the fibre and how it is degraded in the rumen is important to the cow. **Cellulose** is the major energy source for rumen microbes. **Acetic acid** is a major breakdown product and is important for the production of milk and milk fat production. The importance of fibre has been explained in the Energy section above.

Not all fibre or fibre supplements are nutritional. (Some can be useful as bulk in high grain diets.) The ADF from mature forages, straws and cottonseed hulls is poorly digested in the rumen because much of it is indigestible.

How much fibre is needed by the cow?

A minimum level of dietary fibre is needed to promote rumen function and maintain the milk fat test. The fibre content in a diet can be measured as crude fibre, NDF and ADF. In the USA, NDF is used as the main determinant of fibre in the diet. In Australia, NDF is not routinely measured in feeds and, at present, has to be requested as an additional test.

The minimum ADF content in the total ration should range from 19 to 21%.

If NDF values are available for the diet, the following guidelines, although based on US information, may be useful, especially if partial mixed or total mixed rations are fed (routinely or during drought).

The minimum forage dry matter intake (for hays, silages and pastures) is 2% live weight. A 500 kg dairy cow should be eating a minimum of 10 kg DM of forage daily.

The minimum crude fibre content is 17% or NDF content of 25 to 30%. As a rule, 75% of the NDF in the diet should come from forages. If maize silage is fed, the NDF provided by forage should be 30%.

The minimum amount of forage NDF is 0.9% live weight. A 500 kg cow should get at least 4.5 kg NDF from the forage component of the diet. The maximum NDF

Table 1.9: Minimum UDP and RDP needs of cows for various levels of milk production at various weights, and energy (MJME)

Live weight (kg)	Milk production (litres/day)									
	15		20		25		30		35	
	MJ ME	RDP UDP (g)	MJ ME	RDP UDP (g)	MJ ME	RDP UDP (g)	MJ ME	RDP UDP (g)	MJ ME	RDP UDP (g)
450	129	1084 229	155	1302 323	182	1529 411	208	1747 506	235	1974 594
500	134	1126 219	160	1344 314	187	1571 402	213	1789 496	240	2016 584
550	139	1168 209	165	1386 304	192	1613 392	218	1831 486	245	2058 574
600	143	1201 206	169	1420 300	196	1646 389	222	1865 482	249	2092 570

intake for feedlot cows is 1.25% live weight or, for a 500 kg cow, 6.25 kg NDF daily. NDF levels greater than this can decrease dry matter intake because of accelerated gut fill.

Fibre deficiency does not normally occur in pasture fed cattle. Lack of dietary fibre, especially from forage sources, can occur during droughts. Lush spring pastures can be low in NDF. If these pastures are fed with high levels of cereal grains, the ration can lack adequate fibre for maintaining milk fat percentage.

When low fibre diets are fed, buffers may be needed in the ration, especially if cereal grains are fed at greater than 4–5 kg/cow/day.

The length of the fibre source fed is important. The minimum length of forage should be 2.5–3.0 cm. Hay should be longer than 4 cm to be effective as roughage. For silage chop, 15–20% should be 2.5–3.0 cm long, to provide an effective fibre length of 8–10 mm. A shorter chop length will allow better packing of the silage but will reduce the buffering capacity. For maize silage, which contains substantial amounts of grain, a chop length of 11 mm or longer can provide effective roughage, although its buffering capacity can be less than that of other silages.

You should calculate the forage to concentrate ratio of the diet, as it can have an important impact on the milk fat percentage. The length of the fibre can affect this ratio. Long fibre stimulates chewing and salivation, resulting in increased buffering by saliva. On pasture, the minimum forage to concentrate ratio is 60:40. Lower ratios can result in milk fat depression. Forage to concentrate rations of 30:70 are possible for cattle on a total mixed ration, providing the forage source is long chop hay.

One practical method of determining if there is sufficient effective fibre in the ration is to calculate the percentage of cows chewing their cud. If less than 50% of cows are chewing their cud at any time, then there is insufficient fibre in the ration.

Minerals, trace elements and vitamins

These are essential nutrients needed for normal metabolism and the function of different enzymes. The cow's need for these nutrients can vary with her live weight, reproductive stage, level of milk production and other stresses. For example, heat stress increases the cow's requirement for sodium and potassium. The Appendix lists the mineral and vitamin requirements for dairy cattle.

The mineral content of pastures and grain feeds can vary throughout the year, depending on the soil type, irrigation and fertiliser use and the species of pasture or grain grown.

The **macrominerals** required by the cow are calcium, phosphorus, sodium, magnesium, potassium and sulphur. Suboptimal intake of these minerals can result in reduced milk production, reduced fertility and increased incidence of metabolic diseases.

Tropical pastures have a lower mineral content than temperate pastures. This is mainly true for sodium and phosphorus, and for calcium at certain growth stages (see the DairyLink *Managing Pastures* manual); also, different tropical pastures have different levels. The magnesium content in a pasture declines after potash and nitrogen fertilisers are used.

Cereal grains have low levels of most minerals, especially calcium and sodium. Although cereal grains are believed to be a good source of phosphorus, the phosphorus content can vary depending on the level of superphosphate use on the crop.

The **microminerals** required by the cow are cobalt, copper, iodine, iron, manganese, molybdenum, selenium and zinc. The cow needs these minerals in trace amounts. Excessive amounts can be toxic. Deficiencies of these minerals can result in a poor response to infection, especially at calving time. Using micro- mineral supplements can give variable responses in milk production. Supplementing with zinc (as zinc methionine) reportedly improves hoof condition and hardness.

Many of the **vitamins** needed by the cow are supplied by green pasture. When pasture is limited or unavailable, or when the cows are being fed a ration consisting of cereal grains and conserved forage, vitamins A and E will need to be added to the diet. Pastures containing high levels of polyunsaturated fatty acids (such as some clovers) or pastures that have been sprayed with oil or detergent to control bloat can be deficient in **vitamin E** or **tocopherol**.

In the USA, **vitamin A** or **beta carotene** supplementation is required for udder health.

Analysing the diet for minerals and vitamins may not be enough to determine if the cow is receiving adequate amounts. There are many interactions among different mineral and vitamins in the cow, and a deficiency or excess of one mineral or vitamin can affect the function of another mineral and vitamin, even if there are sufficient amounts in the body. Important interactions which can affect the cow's health are the relationships between calcium, magnesium and sodium; calcium and phosphorus; vitamin E, vitamin A and selenium; selenium and copper; selenium and sulphur; and copper and molybdenum. Other components in the diet can affect the levels of minerals and vitamins in the cow. For example, a diet with inadequate protein can inhibit the uptake of selenium even if the diet contains adequate selenium.

Blood, urine and milk testing for minerals and vitamins is a better method for determining if the cow's diet has enough of these components. If deficiencies are found, the mineral or vitamin can be added to the diet as a premix; added to the water supply; directly administered to the cow as an injection or slow release bolus; or included in fertilisers for pastures or crops.

What are the mineral and vitamin requirements of a cow?

The mineral and vitamin requirements of a cow will vary with stage of lactation, the conditions under which she is housed or fed, environmental conditions, the quality of the feed and other components of the feed. Tables 1.10 and 1.11 are recommendations for a 550 kg adult lactating cow producing 25 litres of milk and consuming 20 kg DM daily. They should be used as a guide for the level of minerals and vitamins that should be supplied in the feed.

If supplemental fat is fed, the calcium level may need to be increased to 0.95% and magnesium level increased to 0.30%.

In hot conditions, increased levels of magnesium (0.30%), potassium (1.30–1.50%) and sodium (0.50%) may be of benefit.

Table 1.11 shows the recommended requirements of the fat soluble vitamin A, D and E for a 550 kg cow producing 25 litres per day, consuming 20 kg of dry matter daily. This table would be of use if the ration to be fed was a total mixed ration where the cows had no access to fresh pasture. Vitamin K, another fat soluble vitamin, is not required in the ration because it is synthesised in the rumen.

Table 1.10: Recommended mineral requirements for lactating dairy cattle

Mineral	Recommended range in ration	Maximum level in ration	Estimated amount/day
Macro-minerals			
Calcium	0.43ñ0.77	2.0	116 g
Phosphorus	0.28ñ0.49	1.0	75 g
Magnesium	0.20ñ0.25	0.50	41 g
Potassium	0.90ñ1.00	3.0	184 g
Sodium	0.18		37 g
Chlorine	0.25		51 g
Sulphur	0.20ñ0.25	0.40	41 g
Micro-minerals			
Cobalt	0.10	10	2 mg
Copper	10	100	204 mg
Iodine	0.60	50	12 mg
Iron	50	1000	1020 mg
Manganese	40	1000	816 mg
Selenium	0.10		3 mg
Zinc	40ñ60	500	816 mg

What feeds supply these nutrients?

(Also see the DairyLink *Managing Pastures* manual.) Pasture supplies all of the nutrients required by the dairy cow. This statement might be surprising, but within limits it is true. Unfortunately, the ideal pasture does not occur on all dairy farms, nor does it exist throughout the year. The species of pasture, the season of the year and how effectively the pasture is used affect the quality of nutrients supplied to the cow. These conditions also determine the quantity of pasture available.

Deficiencies of both the quality and quantity of nutrients can occur in pasture, and you should know how and when to use supplements to correct these deficiencies. This is the basis of ration balancing. This section examines the

Table 1.11: Recommended vitamin requirements for dairy cattle on total mixed rations

Vitamin	Unit	Ration levels		
		Recommended	Maximum	Estimated amount per day
A	IU/kg	3260 - 4000	67,500	65250
D	IU/kg	1000	10,000	20,250
E	IU/kg	16	2025	315

feedstuffs that can supply different categories of nutrients.

Energy supplements

Cereals

Cereal grains and their by-products are the main sources of energy supplements. These supplements can be fed whole, or as part of a pelleted ration or ration mix.

As a rule, the dry matter and energy contents of most cereal grains are similar. The main exception is oats, which can be lower in energy. By contrast, the protein content of grains can be very variable and can range from less than 6% crude protein to over 16% crude protein. It is a good idea to analyse cereal grains for crude protein content with each harvest shipment; never assume that the next shipment will be similar to the last.

Cereal grains can be poor sources of UDP (except for maize and sorghum). Grains are medium–high in phosphorus but low in calcium.

A large percentage of whole grain can pass through to the faeces undigested, resulting in a loss of energy to the cow and loss of money to the farmer. Usually the contact time between the rumen microbes and whole grain is too short for the grain seed coat to be broken down. Consequently the grain is poorly digested.

All grains, with the possible exception of oats, benefit from some degree of processing, because it makes the grain more accessible to digestion in the rumen. The degree of processing needed for a grain depends on its starch content. With processing, the grain starch and soluble carbohydrates (NSC) become more available to the rumen microbes and the rate of rumen fermentation increases.

Wheat, barley and triticale should be rolled or cracked. These grains contain the highest amounts of starch. Corn and sorghum require fine grinding or hammer milling to release their starch. These two grains can also be cooked or steam flaked.

By-product feeds

The production or manufacture of food industry commodities results in the production of waste that has little commercial value as a product. Dairies operating near areas where these commodities are produced can use the waste or by-products from the production process as cattle feed ingredients.

By-product feeds potentially contain chemical residues. Any fruit and vegetable waste, fibre waste or seed from crops that have been treated with pesticides and herbicides, as well as ‘new’ by-products not previously used in cattle rations, should be tested for chemical residues. **Never assume that residue testing has been performed on a feed. Always ask for residue information before you use a by-product feed.**

Some by-product feeds might have a higher energy content than that reported on the feed analysis report. In the absence of more complex and expensive analysis, the energy content of processed or pelleted feed is estimated from its digestibility and may be lower than the true energy content. Biscuit meal may contain vegetable oil, a concentrated energy source, as well as soluble sugars. Citrus pulp, although important as a source of fibre, is also a good source of soluble carbohydrates such as pectin.

Table 1.12 gives an analysis of common energy feeds.

Fats and oils

Fats are a concentrated source of energy that can supply up to 35 MJME/kg DM.

Fats are useful when the maximum amount of grain to forage ration is fed and the diet still cannot meet the cow's energy needs. Milk responses to adding fat can be up to 3 litres, with an increase of 0.33% in milk fat for each kilogram of fat eaten.

Fats that contain all the hydrogen atoms possible in their structure are **saturated fats**. Those which contain less than the maximum amount of hydrogen are **unsaturated fats**.

Unsaturated fats are less stable, have a lower melting point and are more prone to go rancid than saturated fats. Unsaturated fats are found in oilseeds like soybean and cottonseed, and in the oils from these seeds.

Saturated fats are found in tallow and fats of animal origin.

High fat concentrations in the diet (greater than 7% of the ration) can have negative effects on rumen digestion and microbial growth. Feeding saturated fats reduces the chance of these adverse effects occurring. Vegetable oils should be avoided. Oilseeds such as soybeans and cottonseed can be used, because although they contain unsaturated fat it is released slowly as the seeds are digested.

When you feed fat in a ration the fibre level of the ration should be high, with at least 21% ADF, and an NDF of 28–32%. Calcium and magnesium levels should be raised because these minerals are less available in the rumen, and since rumen bacteria do not benefit from the added

Table 1.12: Analysis of some common energy feeds

Feed	DM%	Metabolisable energy MJME/kg DM		Crude protein (%)		NDF (%)
		Average	Range	Average	Range	
Cereal grains						
Barley	90	13	12ñ13	11	7ñ15	20
Wheat	90	13	12ñ13	12	9ñ16	12
Oats	90	11	9ñ12	9	6ñ13	26
Triticale	90	13	12ñ13	12	8ñ16	8
Maize	90	14	12ñ16	10	7ñ14	9
Sorghum	90	10	7ñ13	11	6ñ15	10
By-products [+]						
Wheat pollard	90	11		17		36
Biscuit	84	11	10ñ13	8	4ñ12	18
Citrus pulp	18	10	8ñ11	8	6ñ11	23
Brewersí grain	25	10	9ñ11.5	23	21ñ26	42

[+] These are only the commonly used by-product feeds. Many by-products from a number of agricultural industries can be used in cattle rations. The analysis for a number of the feeds is listed in several Australian publications, for example: the *Funny Feeds* booklet from NSW Agriculture; *Dairy Cattle Production*, Proceedings No.161, a 1991 publication available from the Post Graduate Foundation in Veterinary Science (phone 02 9264 2122); and the CAMDAIRY computer program.

energy as fat, the level of UDP in the ration should also be increased. Fat should be added gradually to the diet because it can reduce palatability of the diet.

Protected fats bypass the rumen and are digested in the small intestine. These fats can be fed at higher levels without affecting rumen digestion. However, they are very expensive and should be fed only to high producing cows in early lactation—these cows will be losing live weight at a rate that can affect their future fertility and health.

Most feeds contain some fat. When you add fat to the diet, make sure you account for the fat in the entire ration. If the ration is dusty, up to 1% of liquid fat or oil can be added to settle the dust providing the ration does not already a high percentage of fat.

Buffers

What are buffers?

Buffers are substances that help combat the reduced pH that can occur in the rumen from the formation of acids. Saliva is a natural buffer that contains sodium bicarbonate and sodium biphosphate. Feed additives used as buffers include sodium bicarbonate, magnesium oxide (causmag), sodium bentonite and limestone. These feed additives vary widely in their ability to buffer the rumen from very effective to useless.

Why do we need buffers?

Under normal conditions, saliva buffers the formation of acid products in the rumen. Saliva is produced in response to a fibrous diet, which stimulates chewing.

When cows are fed large amounts of cereal grains, the starch in the grain is rapidly fermented to produce lactic acid. This acid has a greater ability to reduce rumen pH than the volatile fatty acids normally released from fibre and protein digestion. The end result is a build-up of acid products in the rumen. The microbes capable of breaking down these acid products can be overwhelmed, so that they slow down production of the by-products needed by other microbes (including those that digest fibre) for growth. As fibre digestion decreases the rumen function slows, and the cow's appetite drops.

This condition is called **lactic acidosis**. It can sometimes occur if cows are fed a 'slug' of cereal grain in the bails during milking.

The risk of lactic acidosis can increase dramatically with some grains if they are processed. Milling or crushing can make the grain starch more readily available for digestion in the rumen. **Wheat** and **triticale** have a high starch content and are highly rumen-digestible (about 60% is digested in the rumen). The risk of acidosis is greater using these grains, so they should be coarsely processed.

The risk of acidosis is lower with whole, uncracked **barley** and **oats**, which have a rumen digestibility is about 40%. Oats, which have a fibrous husk, stimulate greater saliva production and more natural buffering than other grains. Cracking the grains increases digestibility.

The least risk occurs with **sorghum** and **corn**. With these, about 30% of the grain starch is digested in the rumen. When they are fed whole or with little processing, many grains appear in the manure. Both grains can be finely processed to improve digestion.

During drought or at other times when there is little pasture or conserved forage, saliva production and its buffering effect is reduced. Take care feeding cereal grains, because the risk of rumen acidosis can be high. Oats, which have a fibrous husk, may be the safest grain to feed if fed whole.

Feeding buffers can reduce the risk of acidosis in diets which are high grain/low fibre or in which the grain portion of the diet is fed separately from the fibre portion (such as in the milking bails). The feed additives which have been used as buffers, the recommended amounts to use and their effectiveness as buffers are listed in table 1.13.

Avoid sudden changes in dairy cattle rations. Such changes would include introducing cattle to grain or changing from one grain type to other (for example, oats to wheat). Rumen microbes should be allowed to adapt to the change in diet—otherwise milk production and cow health will suffer.

Table 1.14 gives a timetable for introducing pasture-fed cattle to 3 kg/head of cereal grain supplements.

After about 3 weeks the cows will have adapted to the grain diet and you will be able to stop adding the buffer.

Protein supplements

Protein can be provided by a number of supplements. Urea is regarded as a protein feed because it is a source of nitrogen for microbial protein synthesis. It can be used as a substitute for true protein in feed rations and is effective when fed with an adequate energy source. Table 1.15 tells you what’s in some common protein supplements.

The protein meals are usually a good source of UDP, although the quality can vary. The UDP levels in vegetable protein meals vary, but generally increase with processing. The manufacturing processes (usually heating and pressing) can vary, and the degree of protection of the protein quality and degradability can also vary. Peanut meal has the same Pdg% as sunflower and safflower meals – that is, 10% greater than that of soyabean meal. Some manufacturers use formaldehyde to reduce the Pdg% of some vegetable meals.

The protein in grain legumes is readily degradable. The percentage of protein in legumes is similar to that in brewers’ grain. The crude protein in brewers’ grain is approximately 30% UDP because of the heat generated by the fermentation process.

Table 1.13: Some feed additives used as buffers

Additive	% of total diet DM	kg/tonne of grain	Comment
Sodium bicarbonate	1.5ñ2.0	15ñ20	Neutralises rumen acids. Unpalatable if fed at more than 4% of ration. Can clump if feed is moist.
Magnesium oxide (causmag)	Up to 1	10	Neutralises rumen acids. Source of magnesium for treatment of grass tetany. Do not use in springer or close-up rations.
Sodium bentonite	Up to 4	Up to 40	Uncertain effectiveness as buffer. Affects intake of grain by moderating grain digestion in rumen.
Calcium carbonate (limestone)	1.5	15	Uncertain effectiveness as a buffer. Source of calcium.

Table 1.14: Suggested timetable for introducing a cereal grain supplement

Day	Grain per cow (kg)	Buffer (for example, sodium bicarbonate) (% of ration)
1	0.5ñ1.0	0.5
3	1.0ñ1.5	0.5
5	1.5ñ2.0	1.0
7	2.0ñ2.5	1.5
9	2.5ñ3.5	2.0

Because of the 'mad cow' scare in Europe there is a voluntary ban on the use of animal protein in cattle rations. A similar ban has existed for the use of chicken litter since outbreaks of botulism occurred in feedlot cattle using this supplement as a protein source.

Roughage supplements

Pastures and conserved forages such as hays and silages provide fibre in the ration. These supplements are usually good sources of energy and crude protein, although the quality can vary as it depends on the maturity of the pasture or crop. Table 1.16 shows what's in some common roughage supplements.

As roughages mature, the NDF percentage increases but the metabolisable energy and crude protein percentages decrease. Hay cut from late-flowering lucerne would be an excellent source of total fibre but would have a lower energy level (8.2) and crude protein percentage (15%) than hay made from early-flowering lucerne (9.2 MJME; 22% CP).

The quality of silage is affected by how it is conserved and stored. When silage is made, the carbohydrates in the original forage are converted into fatty acids. The decreased pH stops bacterial growth, so that the silage remains good until it is fed. You can find out how well the silage has fermented by measuring (in addition to the usual dry matter, crude protein, energy and fibre content) the acidity (pH), the amounts

Table 1.15: Analysis of some common protein supplements

Feed	DM%	Metabolisable Energy MJME/kg DM		Crude Protein (%)		NDF (%)
		Average	Range	Average	Range	
Urea	100	0		250		0
Grain legumes						
Lupins	92	13	12ñ14	31	27ñ41	27
Cowpea	88	13		24	21ñ26	43ñ61
Faba bean	91	12.5		26		n/a
Protein meal						
Soybean	88	13		51		15
Sunflower	93	10		33		40
Cottonseed	85	12		42	37ñ45	30

and types of acids formed during the ensilage process, the ammonia and the NSC. This analysis can be requested from a Feed Analysis Laboratory.

In the UK, silages are graded according to the composition:

Grade I. High sugar levels with some fermentation acids. Mineral acids are added during ensilage.

Grade II. Low-acid silage with high dry matter content. Wilted pasture is ensiled without being damaged by rain or other mishap. Animals usually perform well on these silages.

Grade III. Normal. Contains mainly lactic acid with some acetic acid. The ammonia level is below 10% of the total nitrogen. Animal performance will reflect the chemical composition of the silage and will not be affected by the fermentation products.

Grade IV. High lactic acid content, high energy, low pH (below 4.0). Reduces the cows' dry matter intake unless fed with a buffer such as sodium bicarbonate.

Grade V. Contains highly volatile fatty acids, extensive fermentation with mainly acetic acid, high ammonia, low energy, unstable. Silages of this grading have been damaged through poor storage. The original pasture or crop may have been too wet, or did not contain enough carbohydrate to produce enough acid, and too much of the protein was broken down to ammonia. Cows that eat it have a low dry matter intake because of its slow digestibility.

Grade VI. Highly acid silage with both lactic and volatile fatty acids and low protein breakdown. Reduces the cows' dry matter intake.

Minerals

The mineral content of a feed or supplement is of little value to formulating a ration unless the availability, or digestibility, of the mineral is known. Biological availability tells how a mineral is digested and used by the animal. As the availability of a mineral decreases, the amount of the mineral needed to meet the

Table 1.16: Analysis of some common roughage supplements

Feed	DM %	Metabolisable energy MJME/kg DM		Crude protein (%)		NDF* (%)
		Average	Range	Average	Range	
Hays						
Lucerne hay	85	8.7	8.2ñ9.2	20	15ñ22	49ñ57
Clover hay	88	9.3	8.2ñ10.2	16	13ñ18	40ñ43
Ryegrass/clover hay	84	9		12		49ñ67
Sorghum hay	89	8		8		68
Silages						
Maize silage	30	9.9		8		48
Ryegrass/clover silage	24	9		13		39ñ58
Sorghum silage	30	8		9		68

* ranges reflect early-late maturing of harvest

cow's requirement will increase. The availability is also affected by the level of other minerals in the diet and the age of the stock. Table 1.17 gives the relative availabilities of some calcium, phosphorus, magnesium and sulphur sources for the cow.

Getting value from feed analysis

How accurate are the results from your feed analysis laboratory? The answer is that they are only as accurate as the sample you sent in for testing.

When you are sending in a feed sample for analysis, follow these rules to make sure the results will be accurate:

- **Make sure the sample represents the feed you want to test.**

If a sample is taken from a pasture that contains a mix of different species, it should reflect this mix properly. For example, if the pasture is ryegrass with 30% clover, the sample should contain this same mix.

If you're taking a sample from hay or silage, use a corer. If you want to test a hay shipment, take samples from at least 20 bales to get an average result. If you're testing silage, take a sample from the centre of a round bale, about 10 samples from the face of the pit, or a sample from the silage before it is fed out. Don't take a sample from the outside edge of the bale or pit, as this part has been exposed to air and is

Table 1.17: Relative availabilities of calcium, phosphorus, magnesium and sulphur from common feed sources

	Source			
Relative availability	Calcium	Phosphorus	Magnesium	Sulphur
High	Calcium chloride	Monocalcium phosphate	Magnesium oxide	Calcium sulphate
	Monocalcium phosphate	Monosodium phosphate	Magnesium sulphate	Sodium sulphate
	Dicalcium phosphate	Ammonium phosphate	Magnesium carbonate	Potassium sulphate
		Dicalcium phosphate		Magnesium sulphate
Medium	Calcium carbonate	Sodium tri-polyphosphate	Magnesium chloride	
	Limestone	Defluorinated phosphate		
Low	Forages	Low fluorine rock phosphate	Dolomitic limestone	Elemental sulphur
		Soft rock phosphate	Forages, grains	

Note: Bone meal is not recommended because of concerns over 'mad cow disease'.

usually drier or has deteriorated in quality.

Sample cereal grains and feed mixes from the storage bin, not from the feed bails.

- **Send the sample to the laboratory in a sealed plastic bag.**

  If the sample is dry (such as a cereal grain) this will stop it being lost during transport to the laboratory.

  If the sample is moist (such as pasture) try to remove as much of the air as possible from the bag before it is sealed. This will stop the sample drying out and reduce the risk of moulds developing.

  If the sample is silage, freeze it before transport and send it to the laboratory as soon as possible. Silage contains many volatile components and can deteriorate rapidly when exposed to air.

- **Send the sample to the laboratory immediately.**
- **Select the best test for your type of feed.**

  There are several ways the sample can be analysed at the laboratory. The Near InfraRed (NIR) spectrophotometry method can measure the important components of common feeds such as single forage crops or pastures and single cereal grains. If you want tests on mixed feeds (such as grain mix and pasture mix) or unusual feedstuffs (such as a biscuit meal or silage), or if you want a wider than normal range of components measured, then the feed should be analysed by laboratory methods called 'wet chemistry'.

  Feeds may be sent to other specialist laboratories for analysis for different minerals, vitamins, toxins and moulds.

  Feeds can contain other components that have no feed value but can leave residues in the cow, the calf or the milk. These components are usually contaminants such as pesticides, herbicides, insecticides and other chemicals used in the production or preservation of the feed. Any feed source can contain these contaminants and they should be tested for.

Some examples of how you can benefit from feed analysis

The following examples are based on the information presented in this section. Use them as a guide to determining the nutrient content of the feed you are giving your cows.

Example 1: A cow eats 85 kg of ryegrass pasture a day. A sample of pasture is analysed and the following results obtained:

Dry matter	20%
Nitrogen	3.52%
Crude protein	22%
ADF	24%
Energy	11 MJ of ME

How much crude protein and energy is the cow consuming each day?

Step 1: Calculate the amount of dry matter consumed. The cow is eating 85 kg of pasture of which 20% is dry matter. The remainder is water.

Multiply 85 by 20 and divide by 100 to get the dry matter content of **17 kg**:

$$85\text{ kg} \times 20/100 = 17\text{ kg}$$

Step 2: Each kg of dry matter contains 22% of crude protein. Remember crude protein is calculated by multiplying the **nitrogen** value by 6.25.

Multiply 17 kg by 22 and divide by 100 to get the total amount of crude protein of **3.74 kg**:

$$17\text{ kg} \times 22/100 = 3.74\text{ kg}$$

Step 3: Each kg of dry matter contains 11 MJ/ME.

Multiply 17 by 11 to get the total energy of the diet of **187 MJME**:

$$17 \times 11\text{ MJME} = 187\text{ MJME}$$

Example 2: We have two groups of cows. Each is being fed 22 kg of brewers' grain, but the grain is from two different shipments, A and B. The cows being fed brewers' grain from shipment A are producing 2 litres more milk than those being fed from shipment B. What is the problem?

Feed samples from both shipments were sent for feed analysis. Both shipments have a crude protein percentage of 18% and an energy content of 10 MJME. Shipment A has a dry matter content of 40% and shipment B has a dry matter content of 35%.

The cows fed brewers' grain from shipment A will get (40/100 (DM%) × 18/100 (protein %) × 22 kg) or 1.58 kg of crude protein and (40/100 (DM%) × 10 MJME (energy) × 22 kg) or 88 MJME of energy. Those cows fed from shipment B will get (35/100 (DM%) × 18/100 (protein%) × 22 kg) or 1.39 kg of crude protein and (35/100 (DM%) × 10 MJME (energy) × 22 kg) or 77 MJME of energy.

The lowered milk production in the cows being fed from shipment B is probably due to the lower total protein and energy intake.

Example 3: A cow is consuming 3 kg of a barley – cottonseed meal mix in the bails and is grazing ryegrass pastures. You have used a pasture meter to determine that the average intake of ryegrass pasture per cow is 14 kg dry matter.

The bail mix consists of two 50 kg bags of cottonseed meal to each tonne of barley.

Feed analysis for the barley and cottonseed meal follows:

	Barley	Cottonseed meal
Dry matter	90%	90%
CP	11%	44%
ADF	7%	19%
Energy	13 MJ	11 MJ

The analysis of the ryegrass is the same as in example 1.

Estimate how much crude protein and energy the cow is consuming.

In this example we need to do some calculations on how much barley and cottonseed meal the cow could be getting in the bail feed. We are **estimating** what this cow is eating in the bails. We do not know for certain what the actual content of the bail feed is, even though we know the ingredients. We are assuming that the bail feed is mixed properly, distributing the cottonseed meal throughout the barley grain, and that the feed droppers have delivered 3 kg of this mix to the cow.

Step 1: Calculate the amount of cottonseed meal in the total bail feed. Two 50 kg bags of cottonseed meal are added per tonne of barley. Therefore there are 100 kg of cottonseed meal in each 1100 kg of bail feed (1000 kg of barley and 100 kg of cottonseed meal).

The percentage of cottonseed meal in the bail feed is 100 divided by 1100 multiplied by 100, to give **9.1%**.

$$100/1100 \times 100 = 9.1\%$$

We are also **estimating** the amount of pasture eaten by the cow. She may be eating more than 14 kg dry matter or she may eat less. We have no way of accurately measuring how much she is eating. We know that the entire herd has consumed an average of 14 kg dry matter so we will use the **average figure** for our cow.

Step 2: Calculate the total dry matter consumed by the cow.

The bail feed contains 9.1% cottonseed meal. The cow is consuming 3 kg of the feed. The dry matter content of cottonseed meal is 90%.

Multiply 3 kg by 9.1 and divide by 100. Multiply this answer by 90 and divide by 100 to estimate the cottonseed dry matter intake of **0.25 kg**:

$$3 \text{ kg} \times 9.1/100 \times 90/100 = 0.25 \text{ kg}$$

The bail feed contains (100–9.1) or 91.9% barley. The cow is consuming 3 kg of the feed. The dry matter content of barley is 90%.

Multiply 3 kg by 91.9 and divide by 100. Multiply this answer by 90 and divide by 100 to estimate the barley dry matter of **2.48 kg**:

$$3 \text{ kg} \times 91.9/100 \times 90/100 = 2.48 \text{ kg}$$

The total dry matter consumed by the cow is **16.73 kg** (0.25 [cottonseed meal] + 2.48 [barley] + 14.0 [pasture]).

Step 3: Calculate the total crude protein consumed by the cow.

We need to calculate the amount of crude protein each component contributes to the ration.

(a) Each kg dry matter of cottonseed meal contains 44% crude protein.

Multiply 0.25 kg by 44 and divide by 100 to get the cottonseed crude protein contribution of **0.11 kg**:

$$0.25 \text{ kg} \times 44/100 = 0.11 \text{ kg}$$

(b) Each kg dry matter of barley contains 11% crude protein.

Multiply 2.48 kg by 11 and divide by 100 to get the barley crude protein contribution of **0.27kg**:

$$2.48 \times 11/100 = 0.27 \text{ kg}$$

(c) Each kg dry matter of ryegrass pasture contains 22% of crude protein.

Multiply 14 kg by 22 and divide by 100 to get the ryegrass crude protein contribution of **3.08 kg**:

$$14 \text{ kg} \times 22/100 = 3.08 \text{ kg}$$

The total crude protein content of the diet is 3.46 kg (0.11 [cottonseed meal] + 0.27 [barley] + 3.08 [pasture])

Step 4: Calculate the total energy in the diet consumed by the cow.

We need to calculate the amount of energy each component contributes to the ration.

(a) Each kg dry matter of cottonseed meal contains 11 MJ.

Multiply 0.25 kg by 11 to get the cottonseed energy contribution of **2.75 MJ**:

$$0.25 \text{ kg} \times 11 = 2.75 \text{ MJ}$$

(b) Each kg dry matter of barley contains 13 MJ.

Multiply 2.48 kg by 13 to get the barley energy contribution of **32.24 MJ**:

$$2.48 \times 13 = 32.24 \text{ MJ}$$

(c) Each kg dry matter of ryegrass pasture contains 11 MJ.

Multiply 14 kg by 11 to get the ryegrass energy of **154 MJ**:

$$14 \text{ kg} \times 11 = 154 \text{ MJ}$$

The total energy content of the diet is 189 MJ (2.75 [cottonseed meal] + 32.24 [barley] + 154 [pasture]).