5TH EDITION

FEEDING DAIRY COWS

State Government Victoria

Dairy Australia
Your Levy at Work

Editorial team

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FEEDING DAIRY COWS

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This manual also makes use of information from previously produced nutrition manuals:

Feeding Dairy Cows (1997), Target 10 Nutrition Program; editor G. Thomas

Dairy Cow Nutrition Manual (1997), third edition, Target 10; editors J. Leeman and P. Groves

Feeding Tasmanian Dairy Cows (1997), editor B. Fitzgerald.

About this manual

This 5th Edition of the *Feeding Dairy Cows* manual is intended for dairy industry service providers who advise farmers on herd nutrition. The manual is used as a technical resource for the 'Introduction to dairy cow nutrition – a course for service providers' co-funded by DEDJTR and Dairy Australia.

This book has not been designed to be read from cover to cover, but as a reference when seeking specific information on feeding dairy cows.

The contents page lists the topics in each chapter. Throughout the manual, you will see many cross-references which point you to other pages that are relevant to that particular topic.

You may find an 'adviser alert', a brief summary statement or signpost to further information on many of the pages in the chapters. These are generally located either to the left of the main body of text or at the bottom of the page.

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1

THE DIGESTIVE SYSTEM

Ruminants have a complex digestive system which enables them to digest fibrous plant material. Each of the four chambers of a cow's stomach has a specific role to play in the breakdown of feed. Most nutrient absorption occurs when digesta reaches the small and large intestines.

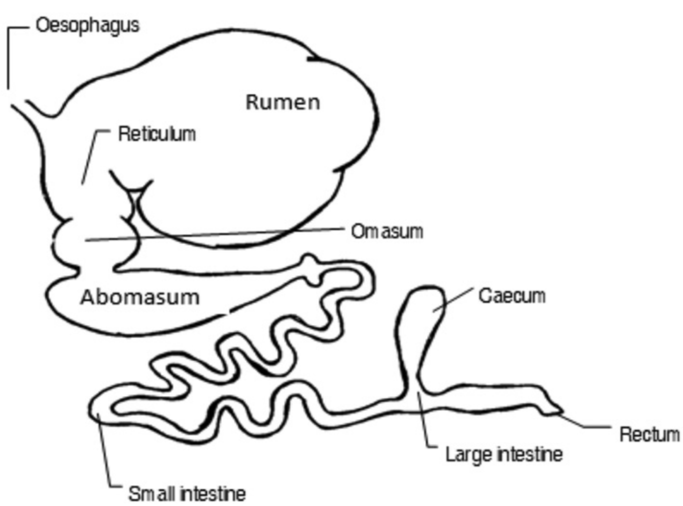
RUMEN-RETICULUM

Once feed has been ingested it is briefly chewed and mixed with saliva. The process of breaking down feed begins here: with the mechanical action of chewing.

Saliva makes chewing and swallowing easier. Depending on the time spent eating and ruminating, a cow can produce 150 litres or more of saliva in a day.

Once the feed and saliva is swallowed, it passes down the oesophagus into the rumen and reticulum. The reticulum is separated from the rumen by a ridge of tissue and the walls of both chambers move continuously, churning and mixing the ingested feed.

Together, the rumen and reticulum have a capacity of between 150–200 litres of solids and liquid.



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MICROBIAL FERMENTATION

These are the major end products of microbial fermentation.

Volatile fatty acids – mainly acetate, propionate and butyrate. These products of fermentation are the cow's main energy source.

Microbial protein – a major source of protein for the cow.

Gases – mainly methane and carbon dioxide. As these gases are belched out regularly, they are seen as wasted energy.

A range of microorganisms (referred to as microbes) are present in the rumen-reticulum and include bacteria, protozoa and fungi. A stable temperature of around 39 °C provides ideal conditions for them to flourish.

Bacteria and protozoa digest 70–80% of the digestible dry matter in the rumen and different types specialise in the digestion of different components. For example, some 'fibre digesters' utilise cellulose and hemicelluloses while others digest sugars and starch. The number and proportions of each type of microbe vary in response to the animal's diet.

Microbes produce enzymes which are responsible for the chemical breakdown of feed through the process of fermentation. These end products are used by the cow and by the microbes themselves for their own reproduction and cell growth.

The internal walls of the rumen are covered with tiny projections called papillae which increase the surface area and allow better absorption of digested nutrients. The reticulum lining has a raised, honeycomb-like pattern (see photo on p.1.4).

A stable pH range (6–7) is maintained by the continual absorption via the rumen wall of the acidic end products of the microbial fermentation. The addition of the naturally occurring buffering agent bicarbonate, which is present in the cow's saliva, also helps maintain a stable pH.

Chewing the cud (rumination) returns newly eaten feed to the mouth for further chewing, which breaks feed down into smaller pieces. This increases its surface area which in turn makes the feed more accessible to the microbes and the chemicals that break it down. As a result, the rate of microbial digestion is increased.

The rumen-reticulum acts as a major regulator of feed intake. Energy density, particle size, ease of digestion and level of feeding all impact on the rate of passage through the rumen-reticulum.

FIBRE AND THE RUMEN-RETICULUM

As fibre is added to the diet, rumination time increases, which means intake decreases. This could impact on milk yield.

As fibre is reduced, rumination time decreases, which means less saliva is delivered to the rumen-reticulum. This could decrease rumen pH and increase the risk of acidosis.

The time spent in ruminating cycles varies depending on the fibre content of feed. Feed with lots of fibre needs to be re-chewed as particles longer than about 1 mm do not leave the rumen-reticulum until their size has been reduced.

Once feed particles are an appropriate length, the contractions of the rumen-reticulum help the flow of finer particles into the next chamber, the omasum.

OMASUM

The primary function of the omasum is to remove some water and to further grind and break down feed.

Large plate-like folds known as laminae extend from the walls of the omasum and are covered with papillae. These papillae direct the flow of food particles toward the next chamber.

ABOMASUM

When digesta reaches the abomasum, microbial fermentation ceases and acid digestion begins. The lining of the abomasum is folded into ridges that produce gastric juices which contain hydrochloric acid and enzymes (pepsins). This highly acidic environment (pH of around 2) kills rumen microbes and begins the digestion of microbial and dietary protein.

SMALL & LARGE INTESTINE

From the abomasum, food moves to the small intestine where most nutrient absorption occurs due to further enzyme activity digesting microbes and dietary protein.

Secondary fermentation of fibre occurs in the caecum and colon in the large intestine. Around 10–15% of the energy used by the cow is absorbed here along with water, minerals and ammonia. Any feed components not digested at this point are expelled as faeces through the rectum and anus.

This photo of a ruminant stomach has all four chambers visible. The rumen is the largest to the far left. Moving right, part of the oesophagus is present above the reticulum. Next is the omasum, abomasum and part of the small intestine which is folded back towards the left (above the section of the oesophagus). The caecum and large intestine are not shown.

Photo: Dr Karen Petersen, University of Washington
http://courses.washington.edu/chordate/hmpg-biol453.html

DIGESTIVE PROCESSES:
FIVE THINGS CAN HAPPEN TO FEED COMPONENTS.....

1.1 Feed enters the rumen

1.2 It is digested and converted by microbes

1.3 Products of digestion are absorbed across the rumen wall into the bloodstream

or

2.1 Feed enters the rumen

2.2 It is digested and converted by microbes

2.3 It continues along the digestive tract to the abomasum where it is digested by enzyme and acid processes

2.4 It continues to the small intestine where it is absorbed into the bloodstream

or

3.1 Feed enters the rumen

3.2 It is unaffected by rumen microbes

3.3 It continues along the digestive tract to the abomasum where it is digested by enzyme and acid processes

3.4 It continues to the small intestine where it is absorbed into the bloodstream

or

4.1 Feed enters the rumen

4.2 It is unaffected by rumen microbes

4.3 It continues along the digestive tract to the abomasum where it is unaffected by enzyme and acid processes

4.4 It continues to the caecum where it is fermented

4.5 It continues to the large intestine where it is absorbed into the bloodstream

or

5.1 Feed enters the rumen

5.2 It is unaffected by rumen microbes

5.3 It continues along the digestive tract to the abomasum and is unaffected by enzyme and acid processes

5.4 It passes out of the cow in faeces undigested and unutilised

REFERENCES & FURTHER INFORMATION

Chamberlain AT, Wilkinson JM (1998) Feeding the Dairy Cow. Chalcombe Publications: Hampshire, UK.

CSIRO (2007) Nutrient Requirements of Domesticated Ruminants. (Eds M Freer, H Dove and JV Nolan). CSIRO Publishing: Collingwood, Victoria.

Jurgens MH, Bregendahl K (2007) Animal Feeding and Nutrition. 10th Edition. Kendall/Hunt Publishing Co.: Dubuque, Iowa, US.

2

COWS NEED WATER AND NUTRIENTS

All cows require water.

The essential nutrients required by dairy cows are energy from carbohydrates and fats, protein, fibre, vitamins and minerals.

WATER

Water is essential to regulate body temperature. Water is also involved in digestion, nutrient transfer, metabolism and waste removal. Water has structural and functional roles in all cells and all body fluids.

Factors influencing water intake include:

- diet composition and dry matter intake
- weather conditions
- water quality
- water temperature and pH.

Intake of water is a combination of drinking water and water from the feeds that cows consume.

Water requirements increase as environmental temperatures increase.

An abundant, continuous and clean source of drinking water is vital for dairy cows.

2

Water quality

Stock water should contain no more than 2000 ppm of total soluble salts.

The following table shows estimates of cow water requirements.

Cow	Daily water requirement
Nonpregnant cows in cool environment – less than 15 °C	• Around 3.5 litres of water per kg of dry matter consumed
Pregnant cows in warm environment – around 21-25 °C	• Up to 7.1 litres of water per kg of dry matter consumed
Lactating cows	• 6 litres of water per kg dry matter consumed • plus an additional allowance of 1 litre of water per litre of milk produced • plus additional allowances for hot weather. • Note that lactating cows can drink up to 150-200 litres water/ day in the summer months.

Many feeds have considerable amounts of water that can help cover an animal's water requirements.

Measurements of water intakes consistently show that intakes are greater than calculated minimum requirements because animals seem to prefer to excrete a dilute, rather than a concentrated, urine.

ENERGY

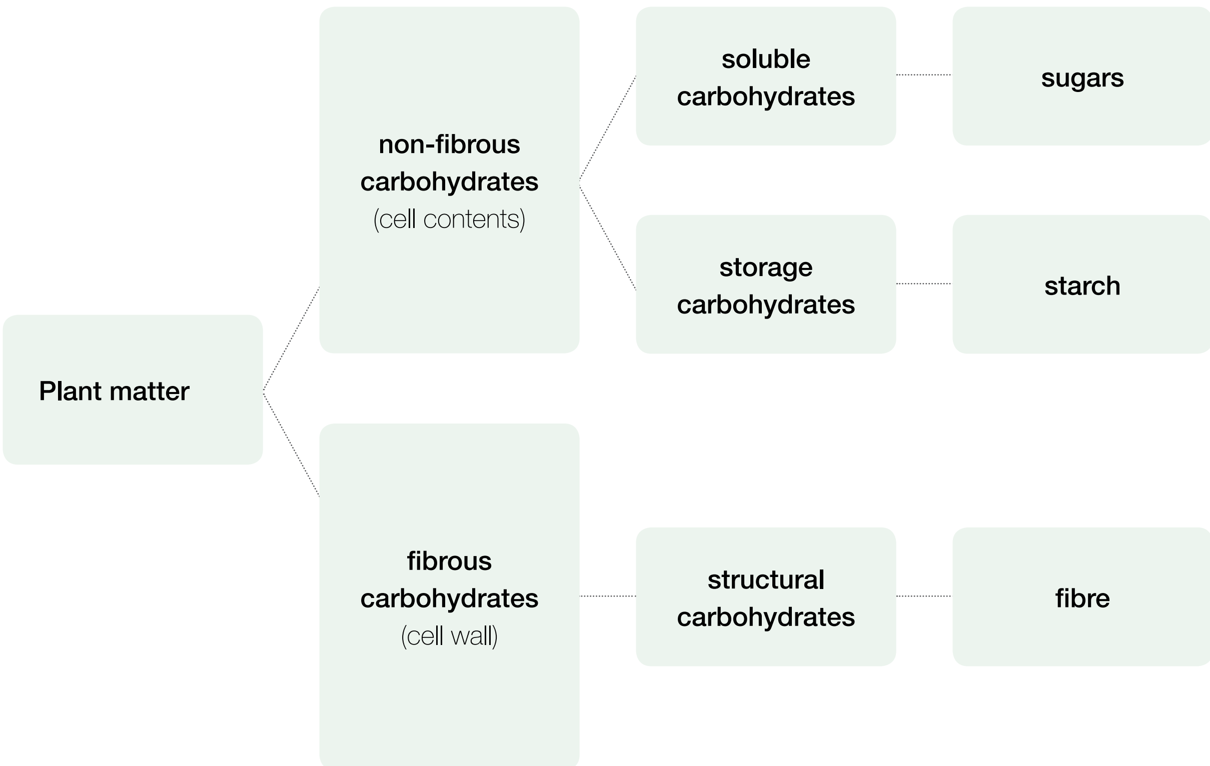
Energy as such is not a nutrient. Energy refers to the sum total of a range of energy-yielding nutrients, normally carbohydrates and fats (lipids).

CARBOHYDRATES: FIBRE, SUGAR & STARCH

Cows need fibre for efficient rumen function. Fibre is required to ensure that the cow chews her cud (ruminates) and produces saliva. Saliva contains sodium bicarbonate which helps stabilise rumen pH. Fibre in the cow's diet also slows down the flow of material through the rumen, giving the rumen microbes more chance to digest feed. Products of fibre digestion are important for the production of milk fat.

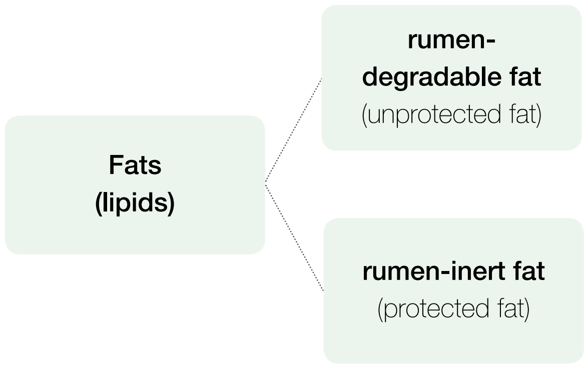
Sugars are the soluble carbohydrates found in the leaves of plants, while starches are more complex sugar subunits of the plant cell.

See Ch 3 for further information.



FATS

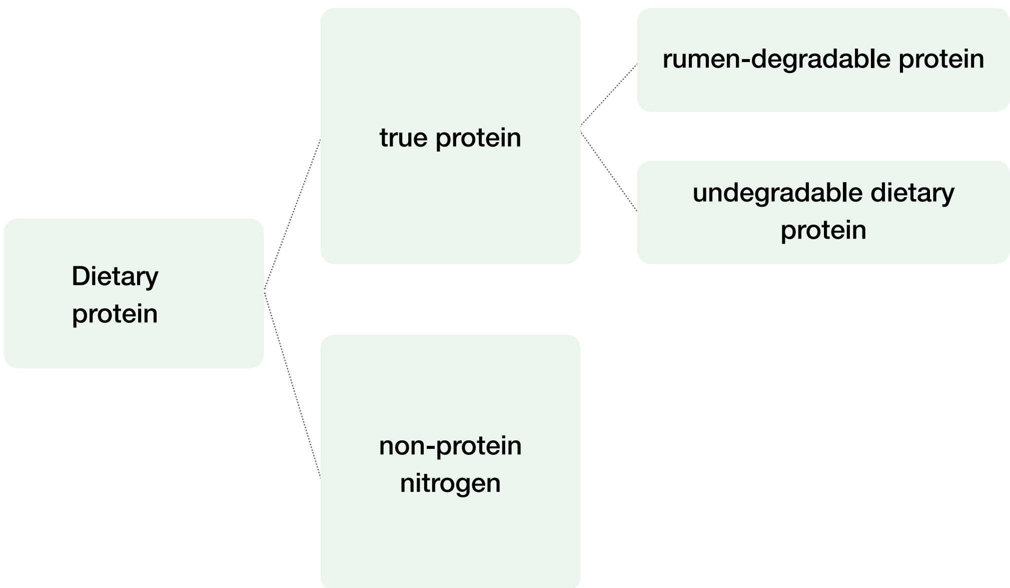
Fats are a concentrated source of energy for the cow. Fats or lipids are present in most of the common dairy feeds in relatively small amounts. See Ch 5 for further information.



PROTEIN

Protein is the material that builds and repairs the body's enzymes, hormones and all the tissues (e.g. muscle, skin, organs, foetus) except fat and bone. Protein is needed for the body's basic metabolic processes, growth and pregnancy. Protein is also vital for milk production.

Protein can also be used to produce glucose as an energy source if necessary. See Ch 4 for further information.



MINERALS

Minerals are inorganic elements. They are needed for teeth and bone formation; enzyme, nerve, cartilage and muscle function or formation; milk production; blood coagulation; energy transfer; carbohydrate metabolism; and protein production.

Minerals are categorised into macro minerals and micro minerals (also called trace elements).

Deficiencies of macro minerals can result in acute metabolic disorders such as milk fever or grass tetany that lead to death if not treated promptly.

Deficiencies of micro minerals are slower to appear and more difficult to diagnose. With 'poor doers', performance often picks up when the deficient mineral is supplied.

See Ch 19 for further information.

VITAMINS

Vitamins are organic compounds that all animals require in very small amounts. Vitamins are needed for many metabolic processes in the body (e.g. for production of enzymes, bone formation, milk production, reproduction and disease resistance).

Requirements are met by content in natural feeds, microbial activity in the rumen and tissue synthesis. Deficiencies are rare but can occur in high-yielding cows in intensive feeding systems.

See Ch 20 for further information.

REFERENCES & FURTHER INFORMATION

Chamberlain AT, Wilkinson JM (1998) Feeding the Dairy Cow. Chalcombe Publications: Hampshire, UK.

CSIRO (2007) Nutrient Requirements of Domesticated Ruminants. (Eds M Freer, H Dove and JV Nolan). CSIRO Publishing: Collingwood, Victoria.

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3 DIGESTING CARBOHYDRATES

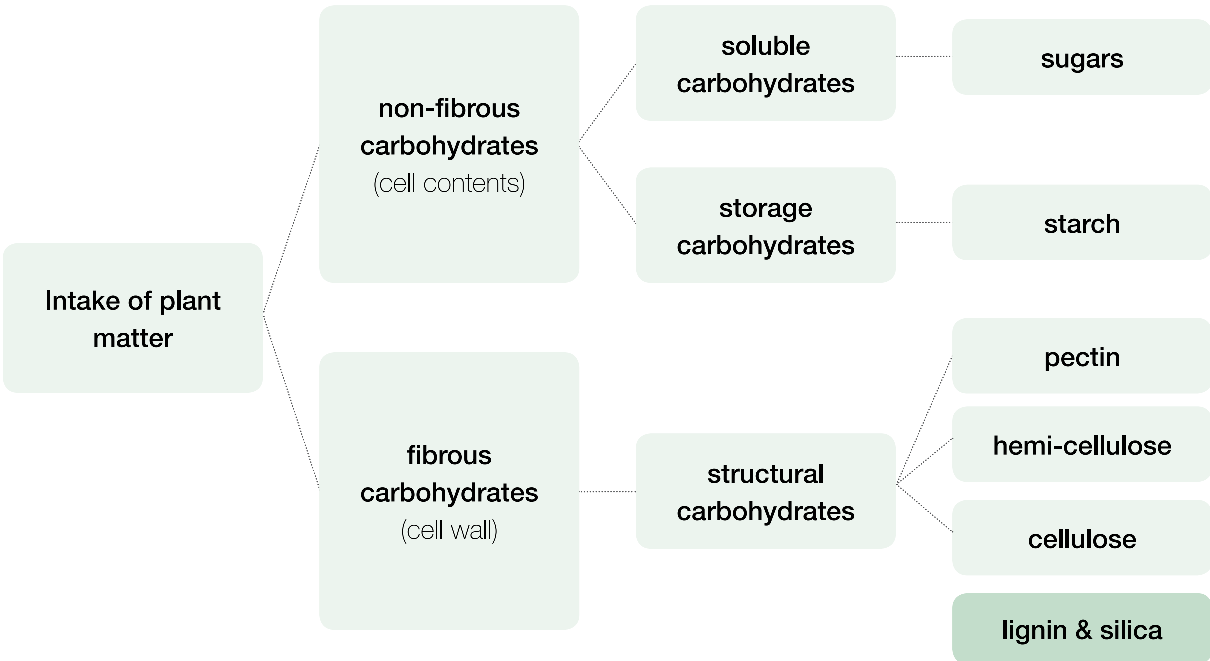
Energy refers to the sum total of a range of energy-yielding nutrients, normally carbohydrates and fats (lipids).

The carbohydrate component of plant matter provides the main source of energy for a dairy cow. Of the plant tissue dry matter that a cow consumes, approximately 75% is carbohydrate.

There are three forms of carbohydrates and all are fermented by rumen microbes. Each type is digested at a different rate.

Soluble and storage carbohydrates are broken down easily and move quickly through the cow's digestive system. By comparison, the cell wall material in structural carbohydrates usually requires more chewing and is digested more slowly.

All carbohydrates are fermented by rumen microbes but the soluble and storage forms are fermented more quickly than structural forms.



Note that lignin and silica provide structural support to plants but they are not carbohydrates. These indigestible components bind to the structural carbohydrates as the plant matures, and they reduce digestibility.

SOLUBLE CARBOHYDRATES

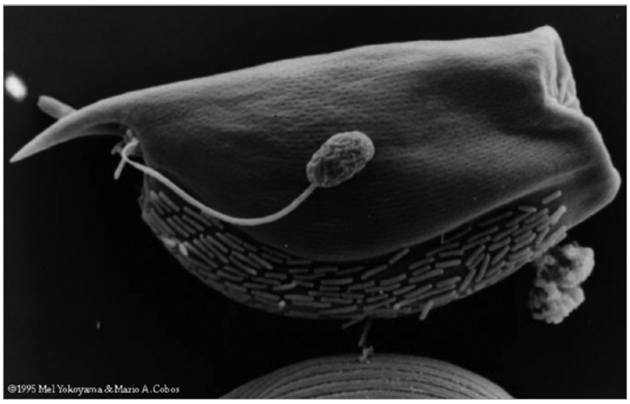
Soluble carbohydrates are the simple sugars found in the cells of growing plants. Leaves have more soluble sugars than stems.

The rumen bacteria that ferment feed high in soluble sugars (like molasses, beets, turnips and good quality grass) are similar to those that ferment starch. Sugary feeds can cause increased acidity in the rumen if consumed in sufficient quantities.

STORAGE CARBOHYDRATES

Storage carbohydrates are the starchy, more complex sugar subunits of the plant cell. They are found in grains, leaf, stem and bulbous roots of fodder crops like turnips.

The rumen bacteria that digest sugary and starchy feeds produce volatile fatty acids and lactate and cause acidity to increase. A rise in rumen acidity caused by excess sugar and starch-digesting bacteria can suppress bacteria that digest the structural carbohydrate cellulose, and may reduce milk fat concentration.



Micro-organisms present in the rumen-reticulum include bacteria, protozoa and fungi. This image shows an example of all three. The large body is of an anaerobic rumen protozoa *Entodinium caudate*. The fungal spore has a tail and the rod-shaped bacteria can be seen underneath.

Photo: Prof. Mel Yokoyama, Michigan State University and Mario A Cobos.

Soluble and storage carbohydrates (sugars and starches) are often referred to as non-structural carbohydrates (NSC) or non-fibrous carbohydrates (NFC).

Structural carbohydrates are the fibre component of a cow's diet.

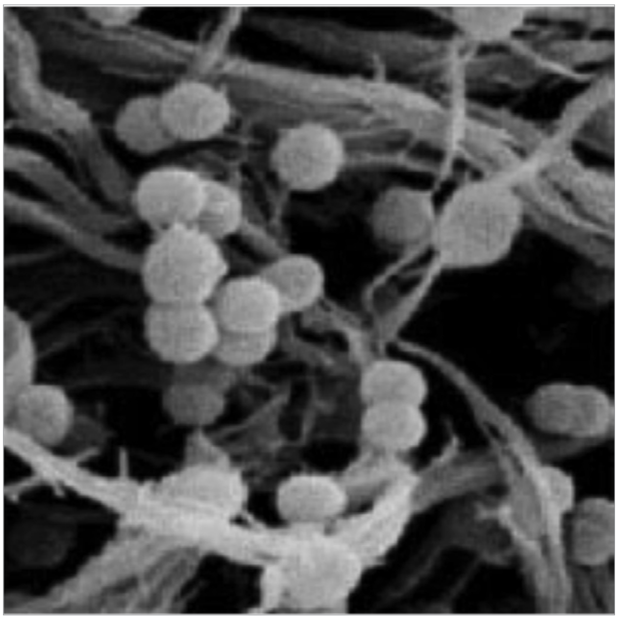
STRUCTURAL CARBOHYDRATES

Structural carbohydrates are the fibrous component of the cell wall of the plant that keeps the plant upright. Large amounts are found in aging, stemmy pasture and in straw.

The rumen bacteria that digest the structural carbohydrate pectin produce propionate. Those that break down cellulose and hemi-cellulose produce a large proportion of acetic acid, which is important in the production of milk fat.

These bacteria are sensitive to fats and acidity in the rumen. If feeds contain too much fat or if the rumen becomes too acidic through feeding rapidly digestible carbohydrates, these bacteria can reduce their growth rate or be completely eliminated.

Reduction or elimination of these bacteria not only reduces the digestibility of the feed; it may also reduce the cow's intake of feed.

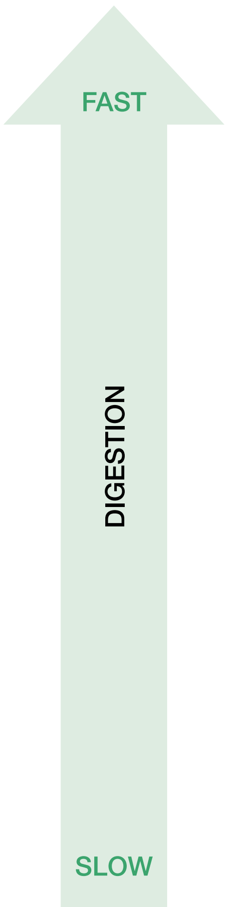


Ruminococcus albus is one example of cellulolytic bacteria which breaks down structural carbohydrates.

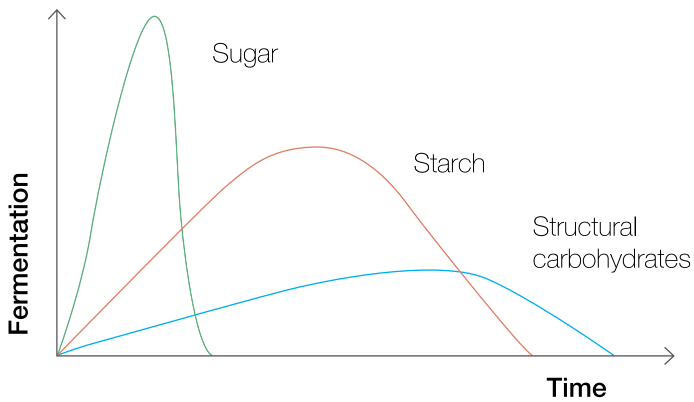
Photo: Prof. Mark Morrison, Ohio State University.

CARBOHYDRATES – RATE OF DIGESTION

Plant cell contents – the soluble and storage carbohydrates – are digested faster than plant cell wall material – the structural carbohydrates.



SUGARS	**Digested almost immediately, 100 times faster than starch**
STARCH	**Digested faster than structural carbohydrates**
STRUCTURAL	**Pectin** **40-60% digested per hour** **Hemi-cellulose** **2-10% digested per hour** **Cellulose** **Lignin silica** **Not digested, excreted**



PROCESS OF DIGESTING CARBOHYDRATES

Almost all carbohydrate is digested in the rumen via microbial fermentation.

The products of sugar, starch and pectin digestion are absorbed across the rumen wall and released into the bloodstream.

Protozoa engulf starch particles prior to digesting them.

Complex polysaccharides are digested to yield sugars that are fermented to produce volatile fatty acids (VFA).

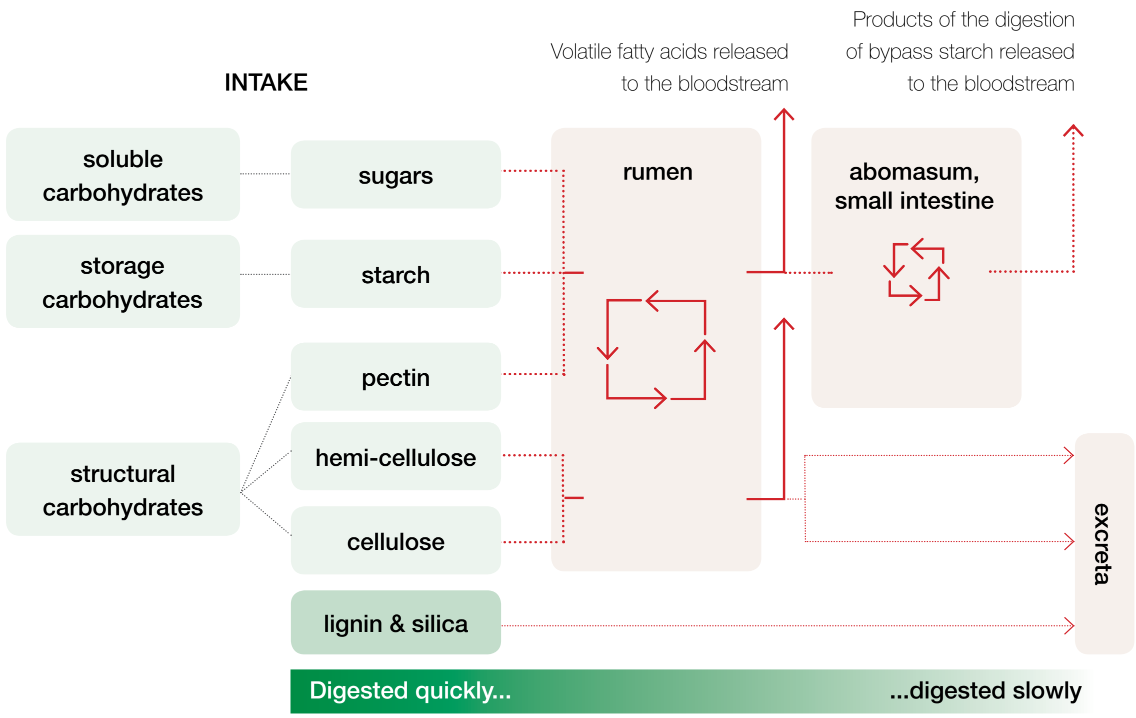
Starches and simple sugars are more rapidly fermented into VFA than fibre components.

Some starch may pass through the rumen and be digested in the small intestine where it is broken down to glucose and absorbed. More starch is likely to be digested in the small intestine when:

- rumen flow rate is higher
- feed particle size is bigger.

The figure below describes the digestive pathway of carbohydrates.

DIGESTIVE PROCESS – CARBOHYDRATES



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The structural carbohydrate components hemi-cellulose and cellulose that cannot be utilised by rumen microbes are eventually excreted.

Microbes attach to fibre components and secrete enzymes.

Cellulose and hemi-cellulose are digested by cellulases and hemi-cellulases.

The plant's structural support components (lignin and silica) are also excreted. Remember, these are not carbohydrates.

Lignin binds to cellulose and hemi-cellulose and makes it less digestible by rumen microbes. The higher the level of lignin in feed, the less energy (ME/kg) it will have. Look for low lignin feeds!

!

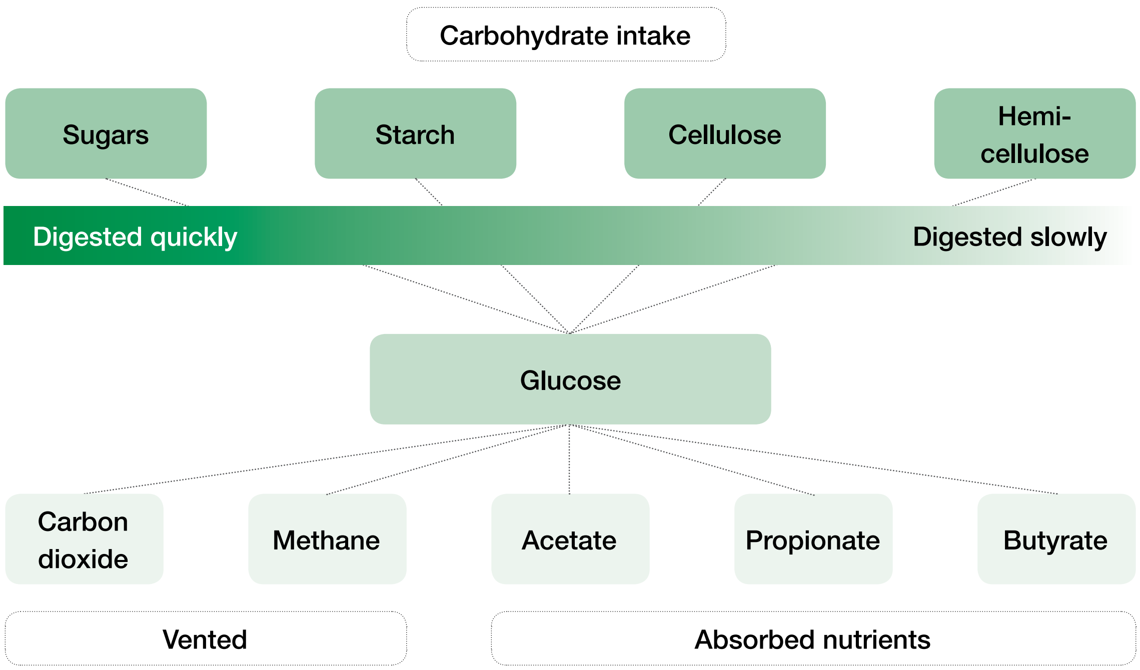
MICROBIAL POPULATIONS

Cellulolytic bacteria (fibre-digesting)	Amylolytic bacteria (starch, sugar-digesting)
Prefer pH 6-7	Prefer pH 5-6
Utilise N in form of NH3	Utilise N as NH3 or peptides
Produce acetate, propionate, little butyrate, CO2	Produce propionate, butyrate and sometimes lactate
Predominate in animals fed high-roughage diets	Predominate in animals fed high-grain diets

PRODUCTS OF CARBOHYDRATE DIGESTION

Carbohydrates are broken down by the rumen microbes to their simplest form (glucose) and then converted to various end products. There are two main groups of end-products of microbial fermentation:

- Gases
- Volatile fatty acids.



Source: Adapted from Chamberlain & Wilkinson 1998.

GASES

Two main gases are produced as a result of the fermentation of carbohydrates but not all of what is produced can be used by the cow:

- carbon dioxide: some is used by intestinal microbes and by the cow to maintain bicarbonate levels in saliva
- methane: which cannot be used by the cow's systems as a source of energy and so is released by belching.

Some ammonia is also produced as a result of carbohydrate fermentation. Microbes use ammonia, amino acids and available energy to produce microbial protein.

Gases resulting from the digestion of carbohydrates are either absorbed through the rumen wall or lost when a cow belches.

VOLATILE FATTY ACIDS

The most important end products of carbohydrate breakdown in the rumen are volatile fatty acids (VFAs).

Volatile fatty acids provide the major source of energy. Around 70% of the cow's total energy comes from these byproducts of ruminal fermentation.

The proportions in which volatile fatty acids are produced may be associated with fat and protein concentrations in milk. See Ch 8 for further information.

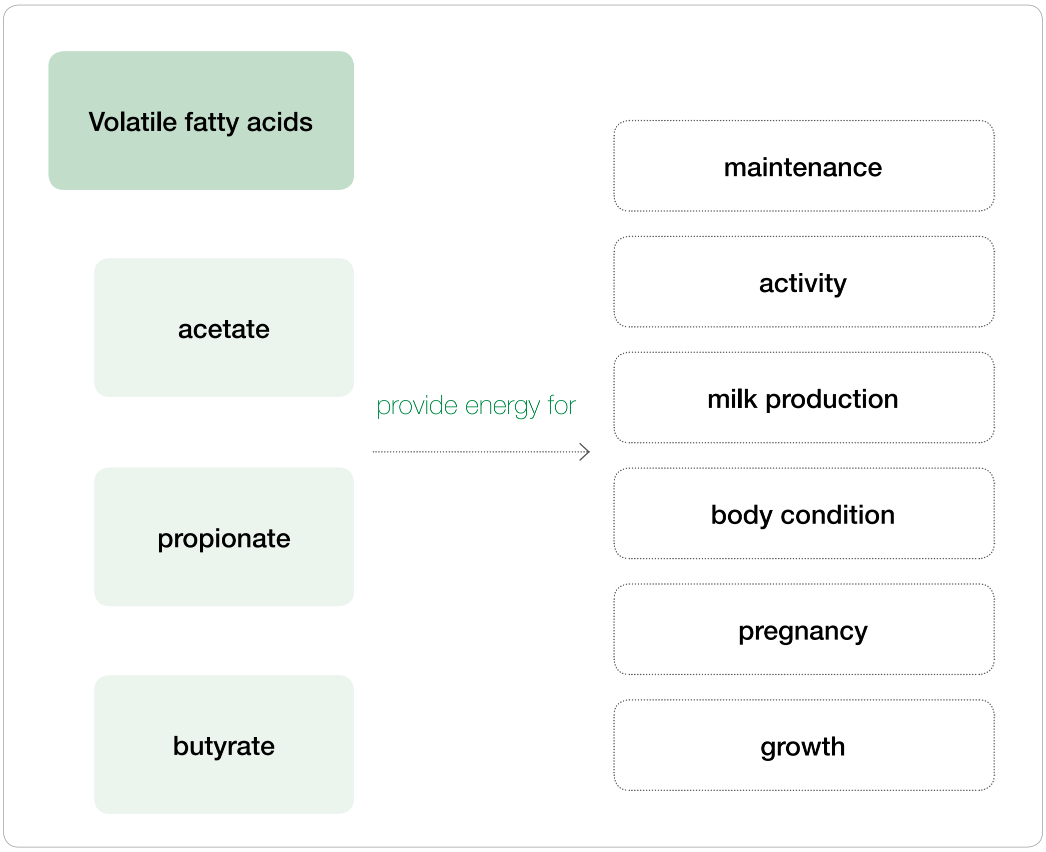
Volatile fatty acids are absorbed through the wall of the rumen and then transported in the bloodstream to the liver.

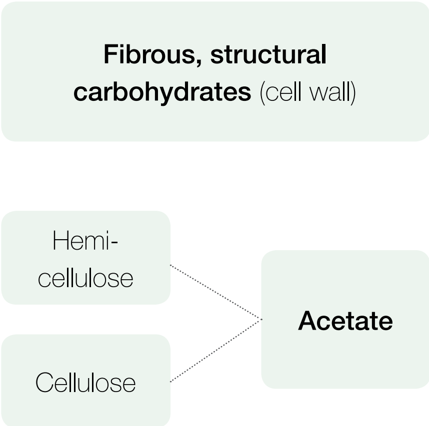
In the liver, volatile fatty acids are converted to other sources of energy. From the liver, the energy produced is used to perform various functions as shown below.

The three major volatile fatty acids produced are:

- acetate – acetic acid
- propionate – propionic acid
- butyrate – butyric acid.

The proportion or ratio of each volatile fatty acid produced depends on the type of feed being digested.



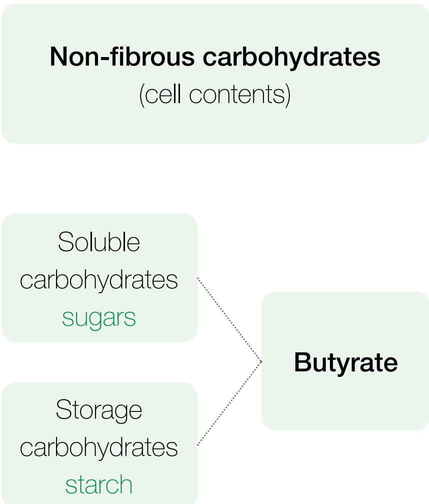


ACETATE

Acetate is an end product of the fermentation of fibre.

Acetate is necessary for the production of milk fat. If acetate production is low, which occurs in diets high in grain (or low in fibre), milk fat production may be depressed.

Highly fibrous, low-energy feeds such as pasture hay lead to microbial populations that produce high ratios of acetate to propionate.

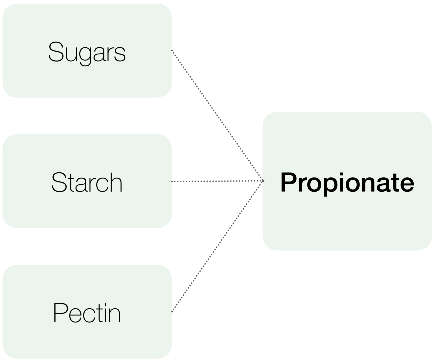


BUTYRATE

Butyrate is an end product of the fermentation of starch and sugars.

Butyrate is metabolised in the liver into ketones. Ketones are used as a source of energy for fatty acid synthesis, skeletal muscles and other body tissues.

Ketones are also produced from the mobilisation of body fat. If a cow is underfed in early lactation and mobilises body tissue to compensate for a lack of dietary energy, ketones are utilised as an alternative energy source.



PROPIONATE

Propionate is an end product of fermentation of starch and sugars and pectin.

Most of the energy needed for live weight gain and for the mammary system to produce lactose is obtained from propionate. Propionate is considered a more efficient energy source because fermentations that favour the production of propionate produce more glucose and less methane and carbon dioxide.

If too little propionate is produced, which can occur during the feeding of high-fibre diets, the synthesis of milk lactose and overall milk yield is reduced. To compensate for the energy deficit caused by insufficient propionate, body fat is mobilised and the cow loses body condition.

Feeds high in rapidly fermentable carbohydrates such as cereal grains lead to populations of bacteria that produce relatively more propionate and butyrate than acetate.

The rough rule of thumb to remember is:

high-fibre diet: high acetate

high sugars/starch diet: high propionate.

REFERENCES & FURTHER INFORMATION

Chamberlain AT, Wilkinson JM (1998) Feeding the Dairy Cow. Chalcombe Publications: Hampshire, UK.

Jurgens MH, Bregendahl K (2007) Animal Feeding and Nutrition. 10th edition. Kendall/Hunt Publishing Co.: Dubuque, Iowa, US.

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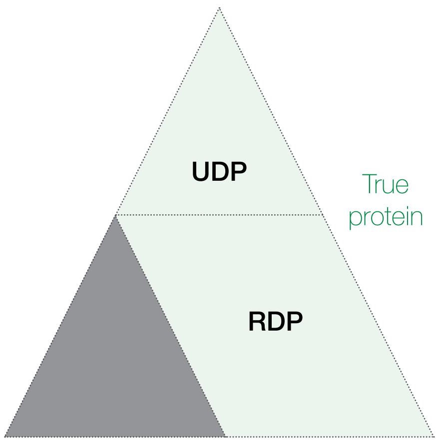
DIGESTING PROTEIN



Protein is present to varying degrees in all the plant matter a cow eats. Dietary protein contains true protein and non-protein nitrogen.

True protein is made up of chains of amino acids. Some of these amino acids, such as lysine and methionine, are essential for the cow's normal body processes. Others are not, and are called non-essential amino acids.

Non-protein nitrogen (or NPN) is the nitrogen in the plant that has not yet been converted to protein.

TRUE PROTEIN

True protein is made up of chains of amino acids which can be:

- used by the rumen microbes to produce rumen-degradable protein (RDP)
- used by the cow directly: this is known as undegradable dietary protein (UDP).

Rumen-degradable protein (RDP)

This protein in the feed is broken down through microbial fermentation to release amino acids. Rumen microbes use available energy and amino acids to reproduce and create microbial protein.

Undegradable dietary protein (UDP)

This protein in the feed escapes fermentation by the rumen microbes.

Together, undegradable dietary protein and microbial protein (see p. 4.8) are broken down to amino acids in the abomasum by enzyme and acid processes and then absorbed in the small intestine.

4

Unavailable protein

A small amount of undegradable protein is completely unavailable to the rumen microbes and the cow. This is called unavailable protein and is excreted.

Damaging the protein through overheating can increase the proportion of protein that is unavailable to the cow.

Protein can be heat-damaged through poorly fermented silage or excessive heat treatment during processing of protein meals. Note that steam pelleting of grain-based dairy feed supplements is not hot enough to damage the protein.

It is important that glucose is metabolised from sources other than amino acids because protein is an inefficient source of energy.

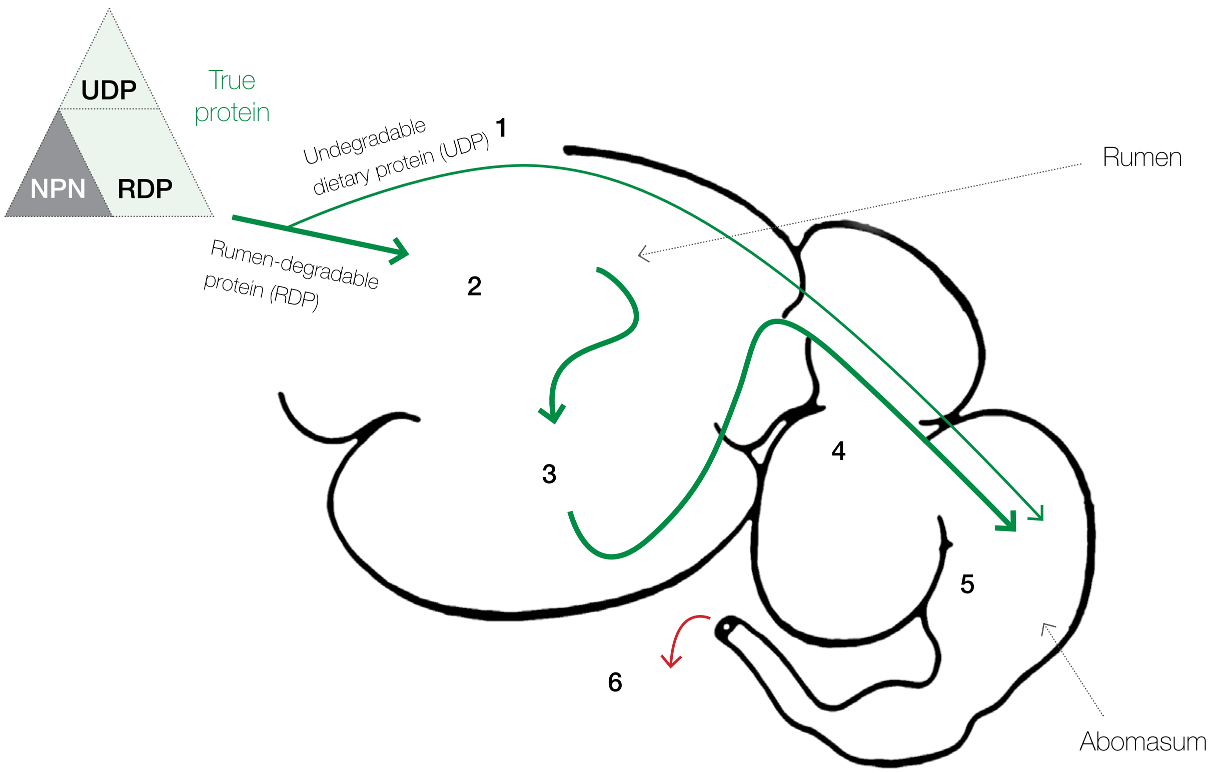
DIGESTING TRUE PROTEIN

The figure below describes how true protein is digested.

1. Undegradable dietary protein (UDP) escapes bacterial breakdown.
2. Rumen-degradable protein (RDP) and non-protein nitrogen (NPN) are converted into ammonia and amino acids.
3. Microbes use the ammonia, amino acids and available energy to produce microbial protein.
4. Microbial protein is flushed from the rumen.
5. Microbial protein and undegradable dietary protein are digested in the abomasum.
6. Once digested, the protein is absorbed into the cow's bloodstream from the small intestine.

DIGESTING TRUE PROTEIN: THE PROCESS

Note: there is usually more RDP than UDP.



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NON-PROTEIN NITROGEN (NPN)

Non-protein nitrogen is the nitrogen in the plant that has not yet been converted to protein. The rumen microbes are responsible for converting this NPN into a form of protein that can be used by the cow.

Rumen microbes convert the non-protein nitrogen into ammonia. Rumen microbes then use available energy and ammonia to reproduce. This creates microbial protein – bug bodies!

If insufficient energy is available to fuel the microbial reproduction, any unutilised or residual ammonia is absorbed through the rumen wall and taken to the liver where it is converted into urea. Here, it is either recycled to salvia or excreted in urine.

!

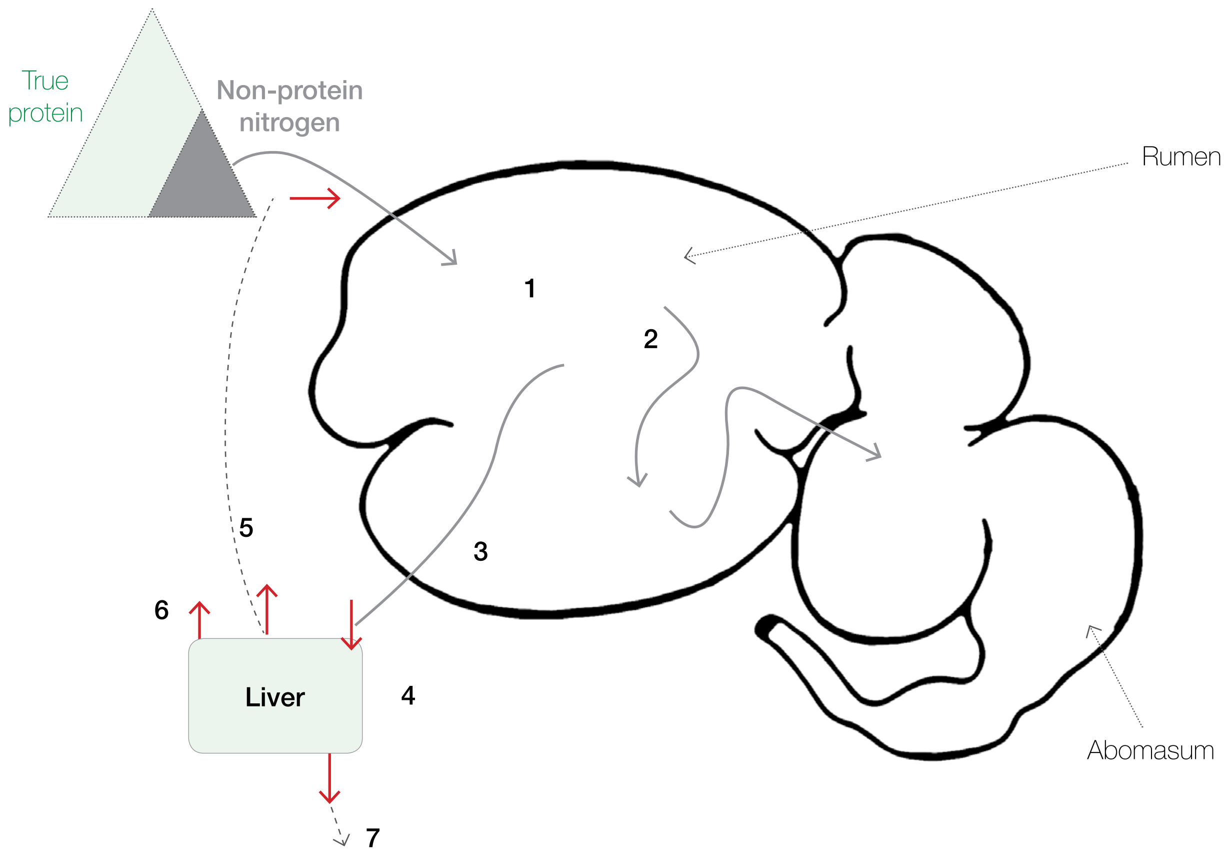
ADVISORY ALERT

In general, the aim is to try to ensure there is enough energy available to use the protein. Otherwise, the ammonia is lost. This costs energy and is inefficient.

Digesting non-protein nitrogen

1. The non-protein nitrogen (NPN) in feed is converted into ammonia.
2. If there is sufficient energy available, some of this ammonia feeds microbial reproduction: microbial protein is produced.
3. Excess ammonia is absorbed across the rumen wall into the bloodstream and goes to the liver.
4. The liver converts ammonia to urea for recycling.
5. Some urea returns to the rumen via the urea in saliva.
6. Some urea is diffused into the bloodstream.
7. Most urea is excreted in urine.

DIGESTING NON-PROTEIN NITROGEN (NPN)



PROTEIN REQUIREMENTS & SUPPLY SYSTEMS

There are a number of different systems used to describe the protein requirements of the cow and the protein supplied in feeds.

The crude protein content of a feed is calculated based on its nitrogen content:

CP% = N X 6.25

Crude protein system

The oldest and simplest way to describe the protein requirements of the cow and the protein supplied in feeds is to use crude protein (CP).

Crude protein does not provide any information about what proportion of the protein feed a cow eats is true protein or NPN, what proportion is digested in the rumen versus further down the gut in the small intestine, and how quickly each proportion is digested.

RDP / UDP system

This system, developed in the 1980s, describes two protein fractions: rumen-degradable protein (RDP) and undegradable dietry protein (UDP).

Rumen-degradable protein (RDP)

RDP consists of both true protein and NPN. The true protein in the feed is broken down in the rumen through microbial fermentation to release amino acids. Rumen microbes use available energy and amino acids to reproduce and create microbial protein.

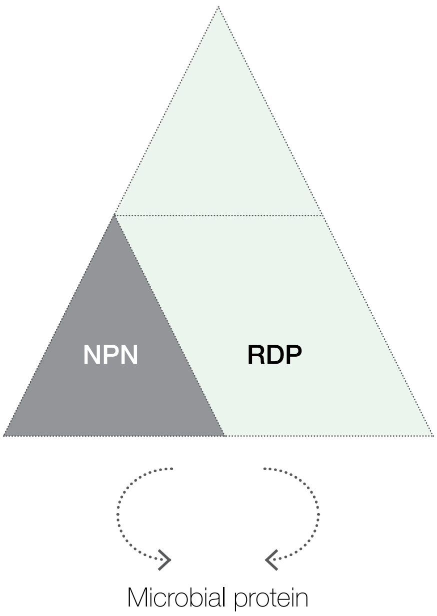
Microbial protein results from the digestion of true protein and NPN in the rumen.

The NPN in the feed is also broken down by the rumen microbes and converted into ammonia. Rumen microbes then use available energy and ammonia to reproduce. This creates microbial protein – bug bodies!

The amount of microbial protein flowing to the intestines depends on the availability of energy in the rumen. If there is not enough energy available, ammonia is wasted and released to the bloodstream across the rumen wall. It is then taken to the liver where it is converted into urea and either recycled to salvia or excreted in urine. If there is enough energy, ammonia is used by rumen microbes for reproduction and microbial protein is the result.

Undegradable dietary protein (UDP)

This is the true protein in the feed which escapes fermentation by the rumen microbes. It is digested in the abomasum with microbial protein, absorbed through the wall of the small intestine and released into the cow's bloodstream.



MICROBIAL PROTEIN

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Microbial protein is very high quality protein because the amino acid profile matches the cow's needs. Rumen microbes are 60% protein and are the major source of protein that cows utilise.

Microbes are continually flushed from the rumen, through the omasum to the abomasum, where they die and are digested. The amino acids produced when microbial protein is digested are then absorbed through the wall of the small intestine into the cow's bloodstream.

Microbial protein flowing to the intestines

If energy is limited...

- Microbes become less efficient at using ammonia.
- Instead of being converted to microbial protein, the ammonia is absorbed across the rumen wall and into the bloodstream.
- In the liver, ammonia is then converted to urea.
- Most of this urea is excreted in the urine, although some is recycled back into the rumen as non-protein nitrogen in saliva. **This process requires energy and is an unproductive use of ingested protein.**

When energy is in excess relative to protein...

- The rate of microbial protein synthesis declines.
- Total protein supply to the cow is reduced and milk yield and milk protein yield decreases.
- Excess energy is converted to body condition rather than milk.
- Pasture-based diets are relatively high in protein. However, when they are excessively high in RDP, as they sometimes are, **the cow needs to expend energy to metabolise and excrete the excess.**

Microbes want balance, so the job of the person feeding the cow is to provide the most balanced diet possible. Always try to match protein and energy availability for efficient microbial growth and reproduction.

In spring when pasture protein levels are high and pasture makes up a large part of the diet, it is difficult to provide enough energy for the microbes to use all the protein. This results in a waste of protein and the cow is forced to expend energy to get rid of the excess.

DIGESTIVE PATHWAY – PROTEIN

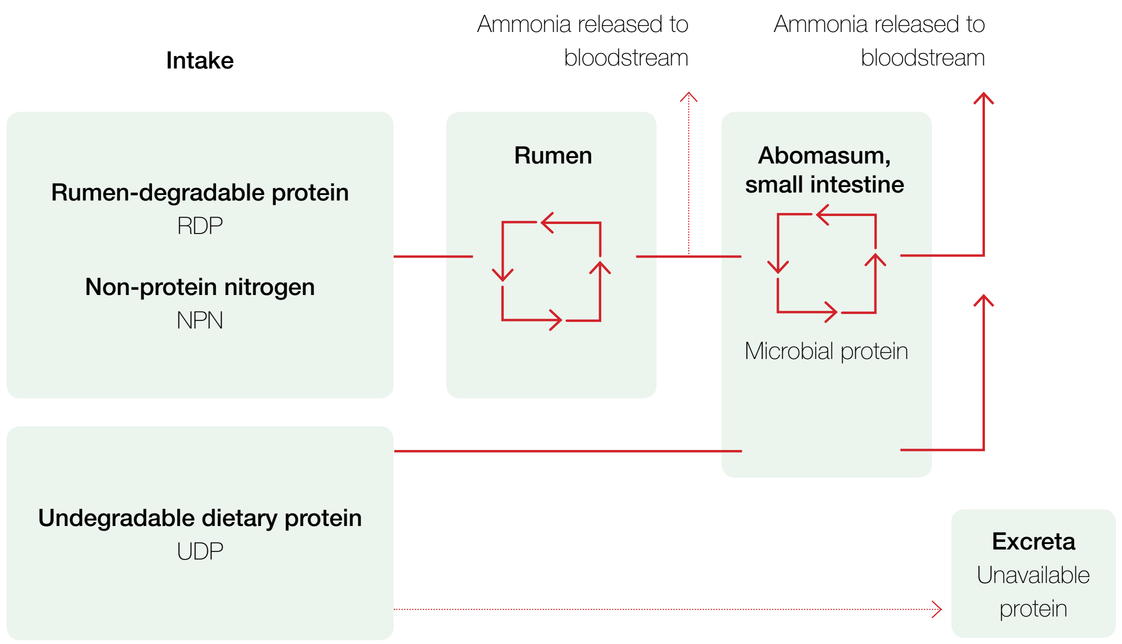
The figure below describes the digestive pathway of protein.

Microbial protein results from the digestion of RDP and NPN. If there is not enough energy available, ammonia is wasted and released to the bloodstream across the rumen wall. If there is enough energy, ammonia is used by rumen microbes for reproduction. Microbial protein is the result. When microbial protein is digested, amino acids are produced. These are absorbed through the wall of the small intestine and released into the cow's bloodstream.

Undegradable dietary protein has two components:

- the part that is digested in the abomasum and small intestine, then released to the bloodstream
- the part that is completely indigestible and unavailable, which is excreted.

DIGESTIVE PATHWAY – PROTEIN



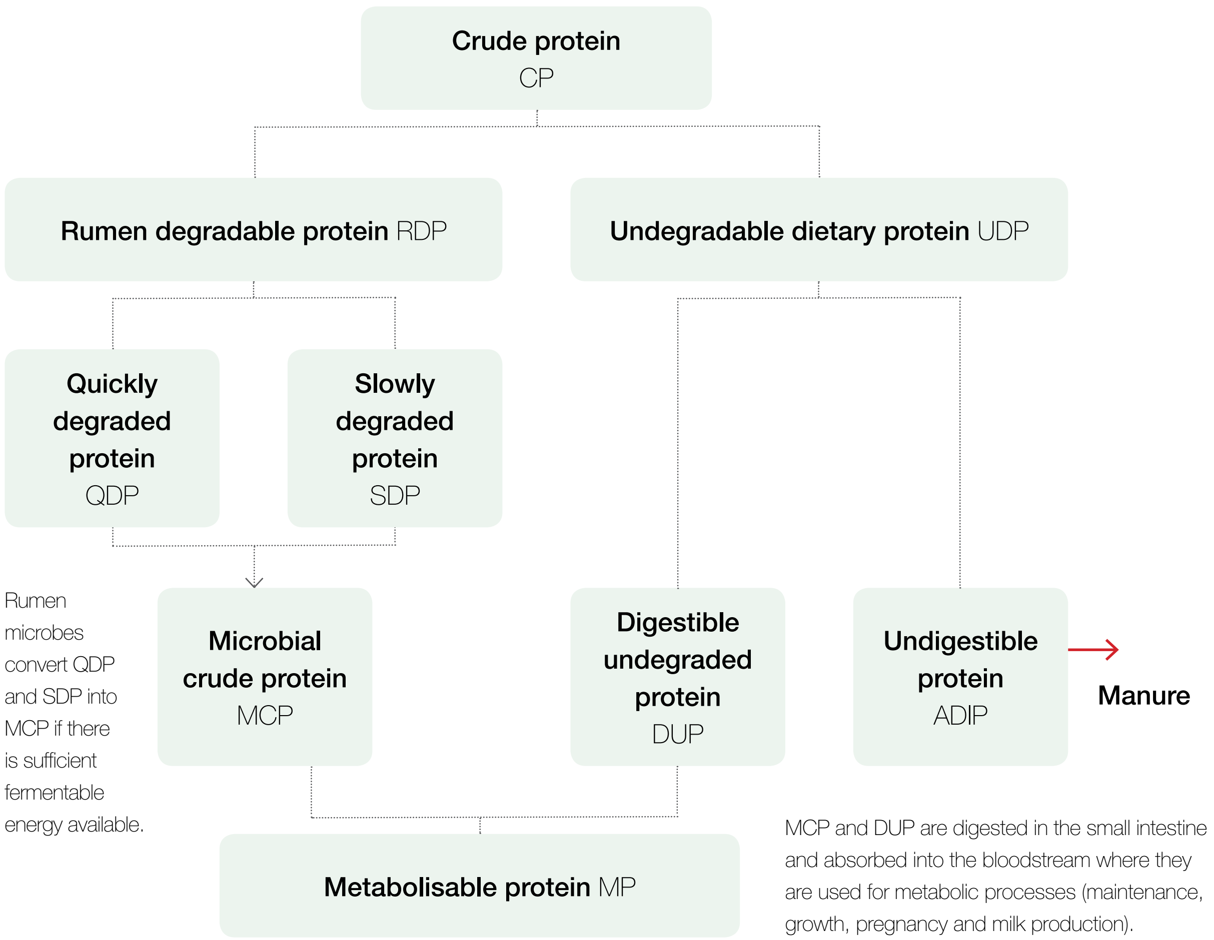
METABOLISABLE PROTEIN SYSTEM

This system was developed in the UK in the 1990s. It still starts with dietary crude protein which is divided into rumen degradable protein (RDP) and undegradable dietary protein (UDP) fractions. It then breaks each of these into 2 fractions:

- RDP into quickly degraded protein (QDP) and slowly degraded protein (SDP) which the rumen microbes convert into microbial crude protein (MCP) provided there is sufficient fermentable energy available
- UDP into digestible undegraded protein (DUP) and completely undigestible protein which is passed out in the manure (ADIP).

Microbial crude protein (MCP) and digestible undegraded protein (DUP) are digested in the small intestine and absorbed into the bloodstream where they can be utilised for metabolic purposes (maintenance, growth, pregnancy and milk production). This is referred to as metabolisable protein (MP).

Source: UK Metabolisable Protein System – Chamberlain & Wilkinson 1998.



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ADVISER ALERT

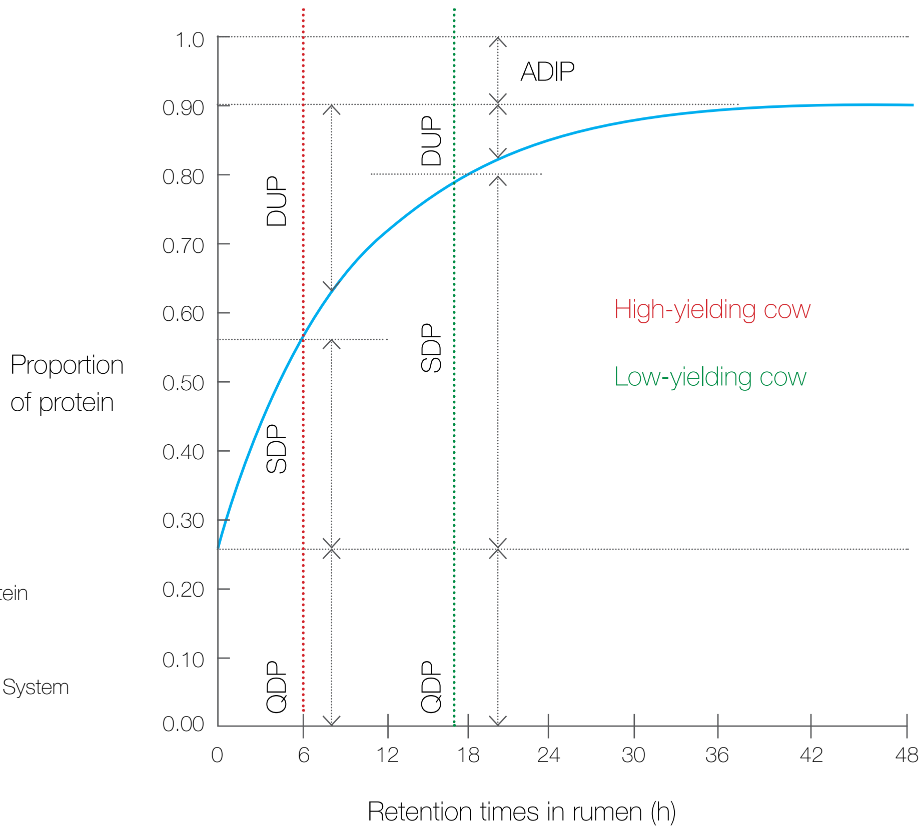
Beware of RDP/UDP values in reference books which suggest they are fixed.

The faster the rumen flow rates, the lower the ratio of RDP/UDP for a given feed.

There are a number of key things to note.

- The RDP and UDP proportions of crude protein in a feed are not fixed as many feed nutrient look-up tables would suggest, but are influenced by the cow's milk production level and other factors.
- A low-producing cow will have a slower rumen flow rate than a higher-producing cow, providing more opportunity for the rumen microbes to break down the protein before it is flushed out of the rumen and passed to the small intestine.
- The proportion of RDP versus UDP in a given feed will therefore be higher in a low-producing cow than in a higher-producing cow, as illustrated in the diagram below.
- The extent to which the protein fractions are broken down and absorbed differs as the numbers in the diagram below show. For example, while 90% of DUP is absorbed into the cow's bloodstream, only 64% of the MCP is absorbed.

QDP, SDP, DUP and ADIP in a feed at different levels of production



QDP Quickly degraded protein
SDP Slowly degraded protein
DUP Digestible undegraded protein
ADIP Undigestible protein

Source: UK Metabolisable Protein System – Chamberlain & Wilkinson 1998.

CPM-Dairy (CNCPS) protein system

The protein system contained in the CPM-Dairy model, developed in the US in the 1990s, is the most sophisticated. It describes five protein fractions and accounts for a feed's passage and digestion rates.

Fraction	Composition	Rumen digestion rates
A	NPN	Instant, very fast
B1	2 – 3 amino acid peptides	Fast, 200 – 300%/hr
B2	Medium degraded protein	5 – 15%/hr
B3	Slowly degraded protein (NDIP – ADIP)	< 2%/hr
C	Unavailable protein (ADIP)	0%

RDP is mainly supplied by fractions A and B1 and some of B2. UDP is mainly supplied by the B2 fraction, with the rumen flow rate influencing how much escapes undigested and passes to the small intestine. For further information, search for CPM dairy model.

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5 DIGESTING FATS

Lipids:
another term for fat – for example, rumen-inert lipids.

Unprotected fat:
fats that are digested or degraded in the rumen, also referred to as rumen-degradable fats.

Protected fat:
fats that bypass the rumen to be digested in the abomasum and small intestine. These are also referred to as rumen-inert fats / lipids or bypass fats.

Fats are a key source of energy for the cow. Fats (sometimes called lipids) are present in most of the more common dairy feeds in relatively small amounts. Fats have the highest energy content of all feeds, but there is a limit to the amount that can be fed.

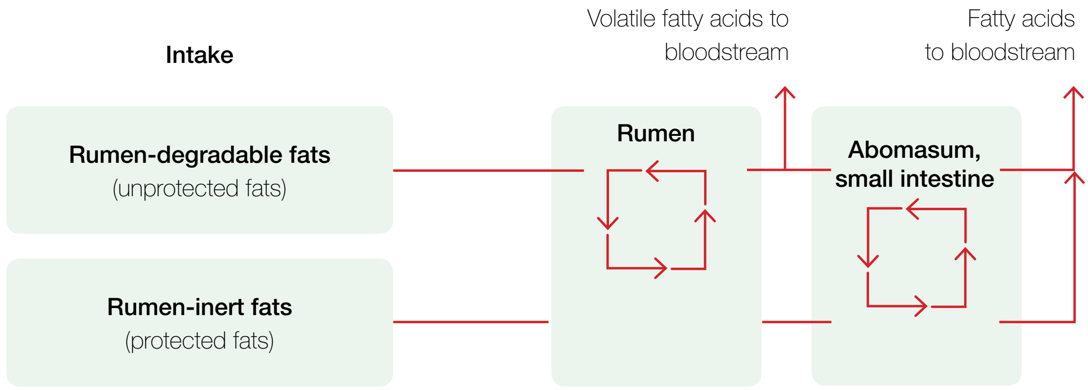
Total dietary fats should not exceed 7% of the feed dry matter and no more than 5% should be unprotected fat (rumen-degradable fat).

Depending on their type, fats are digested in one of two ways:

- they are digested or degraded in the rumen (referred to as rumen-degradable fats or unprotected fats)
- they bypass the rumen to be digested in the abomasum and small intestine (referred to as rumen-inert fats or protected fats).

Note that feeding too much unprotected fat will reduce rumen digestion. A diet should contain no more than 5% unprotected (rumen-degradable) fat.

DIGESTION OF FAT



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RUMEN-DEGRADABLE FATS – UNPROTECTED FAT

Rumen-degradable fat is digested by microbial fermentation in the rumen. Rumen-degradable fats also produce some vitamins required by the cow as a product of this process.

No more than 5% of total diet DM should consist of rumen-degradable fats. Beyond this amount, fibre digestion and dry matter intake is compromised.

RUMEN-INERT FATS – PROTECTED FAT

Protected fats escape microbial digestion in the rumen. These fats are readily digested and absorbed across the wall of the small intestine.

Protected fats can be used to overcome the digestive upsets caused by high levels of rumen-degradable fat. Proprietary fat additive products have been developed for this purpose.

!

DO YOU HAVE A CLIENT KEEN TO INCREASE THE LEVEL OF FATS FED?

What warnings should you sound?

Fats can be an easy way to get more energy into a cow's diet. This is because they are energy-dense and you can get more energy into the cow per mouthful at a time when intake is limited and energy demands are high (that is during early lactation).

Feeding protected fats to high-producing cows (more than 30 L/day) may be useful as fats such as those from oilseeds (e.g. whole cottonseed) increase the energy density of the diet, particularly in early lactation, thus helping to reduce live weight loss.

Feeding fat can also be useful during the lead-up to joining, to improve potential fertility of the cow. Remember though, feeding fat can be risky if you don't know what you are doing.

Always check the type of fat being proposed and understand how it is processed in the rumen. What impact will it have on rumen microbes? Also check total fat in the diet. Remember, total dietary fats should not exceed 6-7% of the feed dry matter and no more than 5% of this 6-7% should be unprotected fat (rumen degradable fat).

Note: some modern ryegrass cultivars can contain up to 7% fat particularly in spring, so may provide little scope for supplementing the diet with other fat sources.

POLYUNSATURATED FATTY ACIDS (PUFAs)

Polyunsaturated fatty acids (PUFAs) are naturally occurring lipids in plants. They are digested in the rumen. When polyunsaturated fatty acids arrive in the rumen they quickly get broken down into their component parts.

The initial processes in the rumen break the structural bonds between the simple sugars, glycerol and unsaturated fatty acids that make up PUFAs.

The simple sugars and glycerol are digested and used in the same way as the soluble carbohydrates. They are used by the rumen microbes to produce volatile fatty acids (VFAs). Volatile fatty acids are the main energy source of the cow. This leaves the unsaturated fatty acids. See Ch 8 for further information.

UNSATURATED FATTY ACIDS (UFAs)

Unsaturated fatty acids (UFAs) are toxic to the rumen bacteria especially fibre digesters so the key question is how do the UFAs become useful?

Rumen bacteria have evolved a biological process as a coping mechanism. This process is called biohydrogenation.

Biohydrogenation

The biohydrogenation process converts unsaturated fatty acids (UFAs) to saturated fatty acids (SFAs).

Once converted to saturated fatty acids, these components are rumen-stable. The saturated fatty acids sit in the rumen until they are physically passed through the digestive tract and absorbed by the small intestine.

Biohydrogenation can only happen at a certain rate, so if you feed too much PUFAs you can expose the rumen to too much UFAs and kill off rumen microbes, particularly the fibre digesters.

!

WAYS TO KILL FIBRE-DIGESTING RUMEN MICROBES

...which you don't want to do!

One way to kill fibre-digesting microbes in the rumen is by flooding the rumen with too much UFAs. You do this as a result of feeding over the recommended maximum level of 5% for PUFAs in the diet.

Fibre-digesting microbes can also be killed off by making the rumen too acidic by feeding too much grain.

5

SATURATED FATTY ACIDS (SFAs)

Microbial fermentation and processing of unprotected fats involves rumen microbes converting unsaturated fats into saturated fats via biohydrogenation.

Rumen-inert fats are rumen-stable. These fats pass through the rumen and are digested and absorbed in the abomasum and small intestine. There are two reasons why this is the case.

1. They may be already saturated. Naturally occurring plant-based saturated fatty acids can be feed to cows and are present in cottonseed, palm kernel and coconut products.

2. Or they may be treated to make them resistant to microbial fermentation (proprietary fat additives).

Remember, animal products contain saturated fatty acids but the ruminant feed ban prohibits the feeding of many types of these products (see below for details).

!

RUMINANT FEED BAN

Australia is free from bovine spongiform encephalopathy (BSE) and other transmissible spongiform encephalopathies (TSEs). Stock feed manufacturers, sellers of stock feed and farmers protect our BSE-free status by rigorous adherence to the Ruminant Feed Ban.

The Ruminant Feed Ban means that the feeding of restricted animal material to ruminants is banned throughout Australia.

Restricted animal material is any material taken from a vertebrate animal. It includes rendered products such as blood meal, meat meal, meat and bone meal, fish meal, poultry meal and feather meal, and compounded feeds made from these products.

Some products are excluded from the ban. Gelatin, milk products, oils extracted from fish, treated tallow or treated cooking oil are allowed to be fed to ruminants like cows.

Dairy farmers must not feed restricted animal material, or compounded feed or meal containing restricted animal material, or any product labelled as containing restricted animal material, to a ruminant. Farmers must also prevent exposure of ruminants to restricted animal material.

DIGESTIVE PROCESSES – PUFAs, VFAs, SFAs

Polyunsaturated fatty acids (PUFAs) are naturally occurring lipids in plants which are processed in the rumen.

The digestion process starts with a breakdown of the structural bonds between the simple sugars, glycerol and unsaturated fatty acids.

The simple sugars and glycerol are digested and used in the same way as the soluble carbohydrates. They are used by the rumen microbes to produce volatile fatty acids (VFAs).

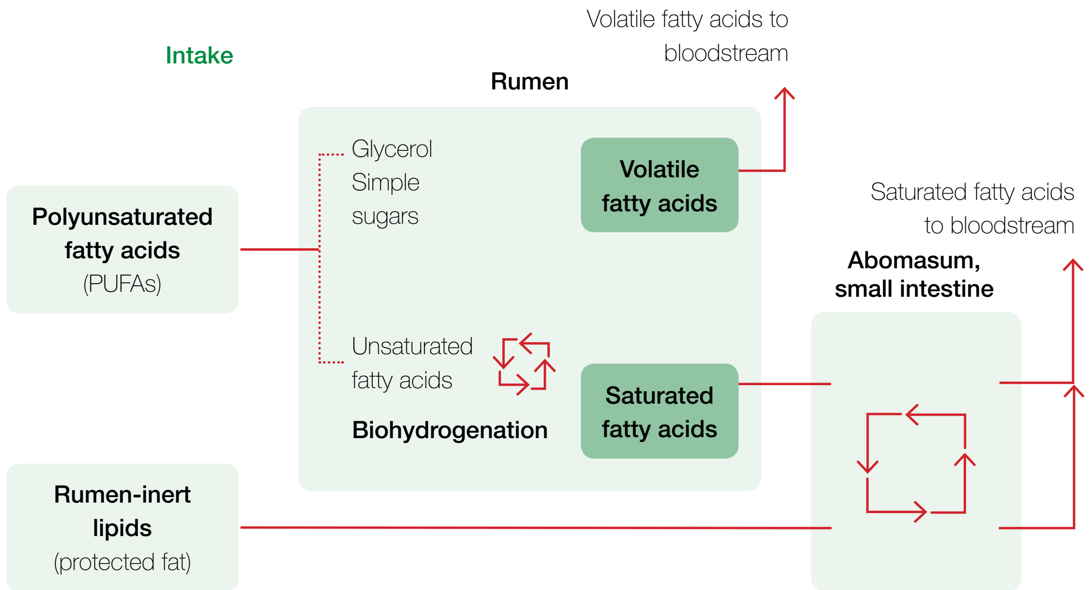
This leaves the unsaturated fatty acids but these UFAs are toxic to the rumen bacteria, especially fibre digesters.

The biohydrogenation process overcomes this problem. Biohydrogenation converts unsaturated fatty acids to saturated fatty acids (SFAs).

Once converted to saturated fatty acids, these components are rumen-stable. They are then physically passed through the digestive tract and absorbed by the small intestine.

Some fat supplements (proprietary fat additives) are rumen-inert or protected to avoid interference with rumen function.

DIGESTIVE PROCESSES – PUFAs, VFAs, SFAs



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6 DIGESTING FIBRE

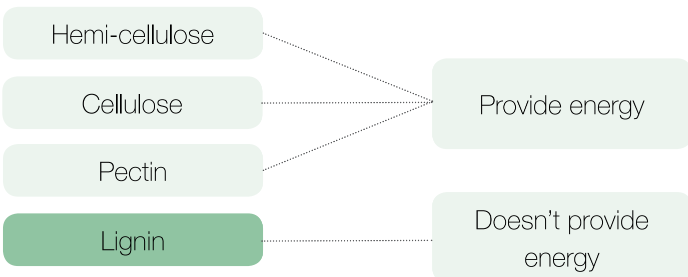
Fibre is the cell wall or structural material in a plant. It is made of hemi-cellulose, cellulose, pectin and lignin. Fibre contributes energy to the diet and is important in the stimulation of saliva production.

Fibrous material present in the cell wall of plant matter provides structure and allows plants to have the form to stand up. Some fibrous material from the cell wall is digestible by the cow and some is not.

- Pectin is present in the cell wall but is digested quickly compared to the other cell wall components.
- Cellulose is a structural carbohydrate and a source of fibre. Approximately a third of plant material is cellulose.
- Hemi-cellulose is also a structural carbohydrate and a source of fibre. It makes up about 20% of plant material.
- Lignin is a structural material that makes up part of the fibre of a feed but is not a source of carbohydrate so doesn't provide energy to a diet. The amount of lignin present depends on the plant's stage of maturity.

The structural materials hemi-cellulose, cellulose and pectin are digestible. As carbohydrates, they provide energy. Lignin is not a carbohydrate and does not provide energy.

Lignin has to be physically reduced in size to pass through the digestive tract. This stimulates chewing and saliva production and helps maintain a healthy rumen.



Fibre promotes chewing

Feeds with long fibre length (more than 1.5 cm) take longer to chew.

Not enough long fibre:
= not enough chewing
= not enough saliva
= drop in rumen pH
= increased risk of acidosis.

For facts about fibre visit www.dairyaustralia.com.au.

6

Too much fibre in the diet (particularly high levels of lignin) slows the rate of passage from the rumen and leads to decreased intake.

High-lignin feeds are usually low in energy and protein, so if levels are high the diet might not be meeting the cows' metabolisable energy (ME) and crude protein (CP) needs.

Fibre in the cow's diet also slows down the flow of material through the rumen, giving the rumen microbes more chance to digest feed. Products of fibre digestion are important for the production of milk fat.

FIBRE, SALIVA & RUMINAL pH

Feed with long fibre length like hay takes longer to chew than less-fibrous feed like lush pasture or grain. The more a cow chews, the more saliva is produced in the process.

Saliva contains bicarbonate and other naturally occurring buffers and cows fed adequate long-fibre diets produce more than 180 L of saliva per day. This is enough to keep the rumen pH at just the right level to suit rumen microbes.

More than 2.5 kg of bicarbonate produced each day in saliva helps maintain the cow's average daily ruminal pH in the optimal range for growth of rumen microbes: 6.2-6.6.

In a healthy cow, ruminal pH fluctuates over a 24-hour period. It can drop to 5.5 or lower for several hours after eating large amounts of highly digestible feeds such as grain/concentrate, silage or lush pasture, before recovering again.

Saliva helps to buffer the rumen pH and prevent the degree of acidity varying too much.

ADVISER ALERT

If animals consume sufficient amounts of highly digestible feeds, ruminal pH drops, leading to reduced growth of fibre-digesting bacteria and increased growth of acid-producing bacteria such as *Strep. bovis*, which continue to acidify the rumen.

If the rumen's natural buffering capacity is overwhelmed, a downward spiral can occur until the rumen shuts down.

Feeding a slower-fermenting long fibre such as hay as soon as possible after grain/concentrate can help reduce the pH drop.

Replacing lush pasture with some hay or straw can also help reduce the pH drop.

Animals with subacute ruminal acidosis (SARA), where the rumen pH is in the range 5.2-5.6, may not appear sick, although feed intake and production are reduced.

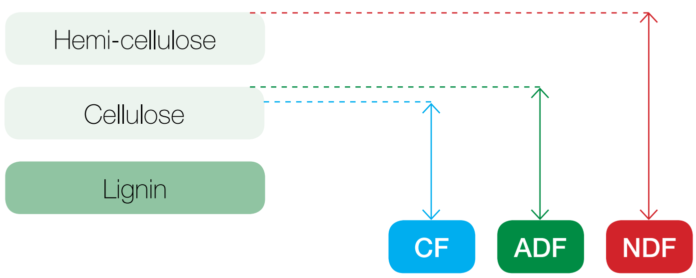
Animals with a ruminal pH below 5.2 will be noticeably sick. They will be off their feed, down in their milk and scouring. This may then progress to Downer cow syndrome and death.

Fibre is defined nutritionally as the slowly digestible or indigestible fraction of feeds that occupies space in the gastrointestinal tract of animals.

There are several ways of describing the fibre in a cow's diet.

- Neutral detergent fibre (NDF) – this is a measure of all the fibre (the digestible and indigestible parts). It indicates how bulky a feed is. A high NDF might mean lower intake because of the bulk. Lower NDF values lead to higher intakes.
- Acid detergent fibre (ADF) – this is the poorly digested and indigestible parts of the fibre – the cellulose and lignin.
- Crude fibre (CF) – this term is used to indicate fibre content, but is now considered an unacceptable measure. It does not include all of the constituents that make up the fibre component of a feed.
- Physically effective fibre (peNDF) – this is the term coined to take into account both the chemical and physical attributes of the fibre in a feed.

Chemical analysis shows the difference in definitions of crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF). NDF is a measure of all fibre – digestible and indigestible.



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NEUTRAL DETERGENT FIBRE (NDF)

Neutral detergent fibre (NDF) is a measure of all the fibre (the digestible and indigestible parts) and indicates how bulky the feed is. Some of it is digested and some is excreted. It is determined by digesting feed samples in a neutral detergent solution and measuring the residue.

Of the current methods routinely used to determine fibre, only NDF measures total fibre and quantitatively determines differences between grasses and legumes, warm and cool season grasses, forages and concentrates, and roughages and energy feeds.

NDF measures the chemical characteristics of the fibre in feed but not the physical characteristics of fibre.

Physical characteristics such as particle size and density can influence:

- animal health
- ruminal fermentation and utilisation
- animal metabolism
- milk fat production.

Physical characteristics influence these independently of the amount or composition of chemically measured NDF.

ACID DETERGENT FIBRE (ADF)

Acid detergent fibre (ADF) is the poorly digested and indigestible parts of the fibre (i.e. the cellulose and lignin). If the ADF is low, the feed must be very digestible (i.e. high quality).

ADF is determined by digesting feed samples in an acid detergent solution and measuring the residue. The ADF residue can then be further digested to determine lignin concentration.

peNDF

To determine physically effective fibre, the NDF of a feed is multiplied by the physical effective factor (PEF) which can range from 0-1:

- **0.0 when NDF is not effective in stimulating chewing activity**
- **1.0 when NDF is fully effective in promoting chewing.**

PHYSICALLY EFFECTIVE FIBRE (peNDF)

The peNDF of a feed is the product of its NDF concentration and its physical effectiveness factor (PEF).

Physically effective fibre or peNDF is now used to describe the effectiveness of fibre at promoting chewing and saliva production.

'Physically effective fibre' is a term that has been coined to take into account both chemical and physical attributes of the fibre in a feed (like particle size and fibre concentration).

peNDF assists in the formation of the ruminal mat, which may be a critical factor for selectively retaining fibre in the rumen, determining the dynamics of ruminal fermentation and passage, and stimulating rumination.

peNDF provides a more consistent measure of physical effectiveness than chewing activity per kg of DM because peNDF is based on the two fundamental properties of feeds that affect chewing: NDF and particle size.

Eating and ruminating increases saliva production above baseline secretions. Note though that the amount and composition of saliva can vary with chewing activity.

When assessing fibre requirements, consider physically effective fibre rather than simply 'fibre'.

!

ADVISER ALERT

Two feeds may have the same percentage NDF but very different peNDF.

For example, palm kernel and ryegrass have the same NDF but very different percentages of physically effective fibre.

Feed	NDF	peNDF
Palm kernel	65%	22%
Ryegrass hay	65%	64%

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7

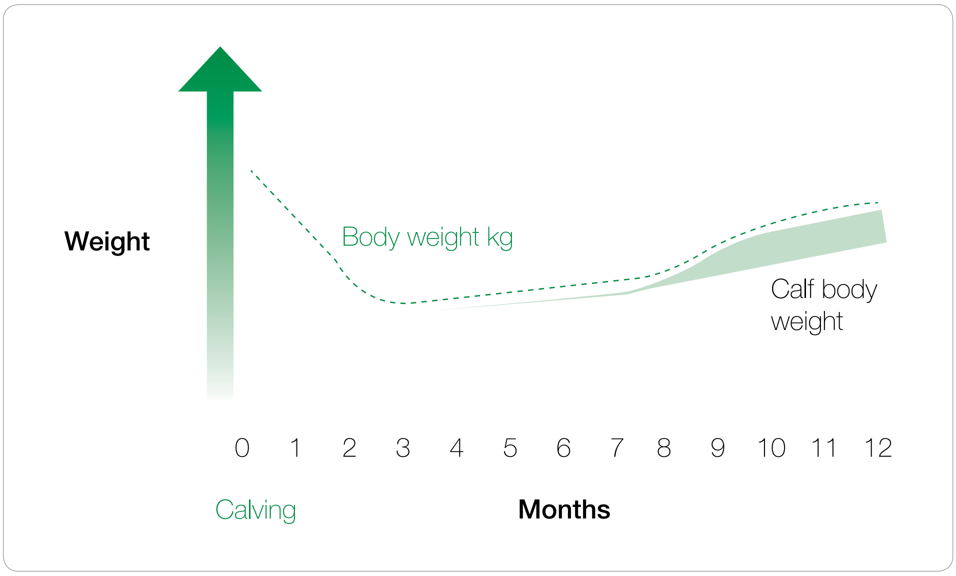
UNDERSTANDING BODY CONDITION CHANGE

7

A cow's body condition changes over the lactation.

A cow is biologically programmed to either store body fat or mobilise it, depending on the amount and type of feed eaten and the stage of lactation.

Breed	Kg of bodyweight per condition score
Jersey (400 kg)	33
Cross-bred (475 kg)	39
Holstein-Friesian (550 kg)	46
Holstein-Friesian (650 kg)	54



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It is important to remember however that body weight alone is not a good indicator of body reserves. This is because the relationship is affected by factors such as the cow's number of calvings, stage of lactation, frame size, gestation and breed.

In addition, because tissue mobilisation in early lactation occurs as feed intake increases, actual decreases in weight can be masked by gut-fill. It is for this reason that numerical body condition scoring systems started to appear in dairy research and on farms in the 1970s.

CONDITION SCORING

Cow body condition score is a visual assessment of the amount of fat and muscle that a cow is carrying.

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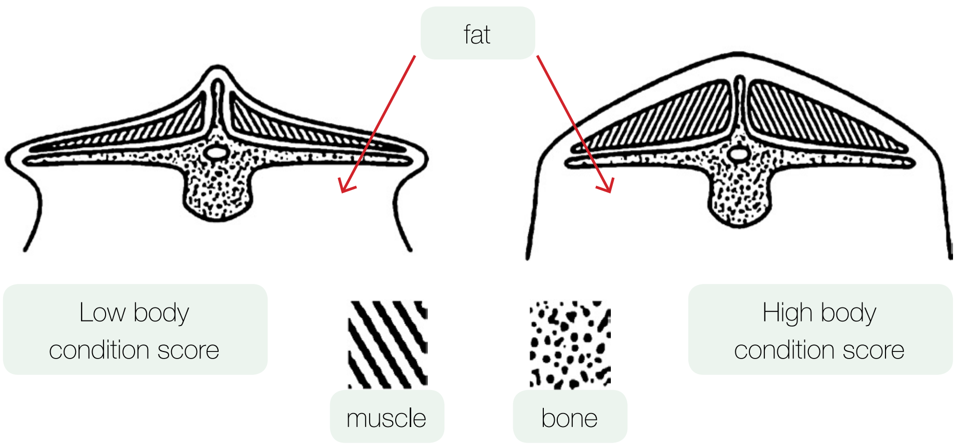

Although many condition scoring systems have been developed, the most commonly used one in Australia is an eight-point scale developed at DPI Ellinbank (Earle 1976).

ADVISER ALERT

There are a number of different body condition scoring scales in use, including those developed in the US and Ireland (1–5 scale) and NZ (1–10 scale). Check to ensure you are using the Australian 1–8 scale. Don't use beef condition scoring scales!

Conversion table

Australian 1–8 scale	US 1–5 scale	NZ 1–10 scale
3	2	1.5
3.5	2.25	2.4
4	2.55	3.33
4.5	2.8	4.2
5	3.15	5.2
5.5	3.5	6.15
6	3.75	7

Source: Roche et al 2009.

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WHY CONDITION SCORE?

There are three key reasons for monitoring and managing condition score through the annual lactation cycle:

1. to optimise fertility

2. to optimise milk production

3. to minimize metabolic disorders in early lactation.

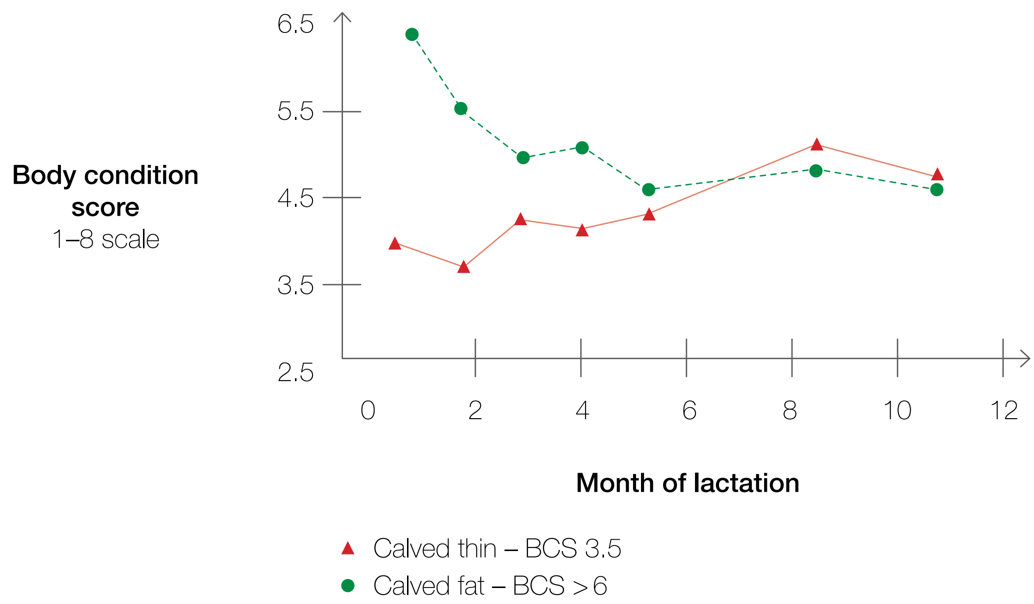
There are five key points to note about body condition score.

1. A cow's body condition score (BSC) increases proportionally with its back fat thickness and total body fat content, so it is a very good measure of body energy reserves.

2. A cow's change in BCS in early lactation is inversely related to its BCS at calving. Cows that are very thin at calving gain condition in early lactation; cows that are fat at calving lose condition in early lactation. The fatter the cow at calving, the more condition lost in early lactation.

3. Regardless of how fat or thin a cow is at calving, the cow has a genetically programmed target BCS at 10–12 weeks into lactation (as per peak milk yield), which the cow will reach if it has sufficient, high-quality feed available.

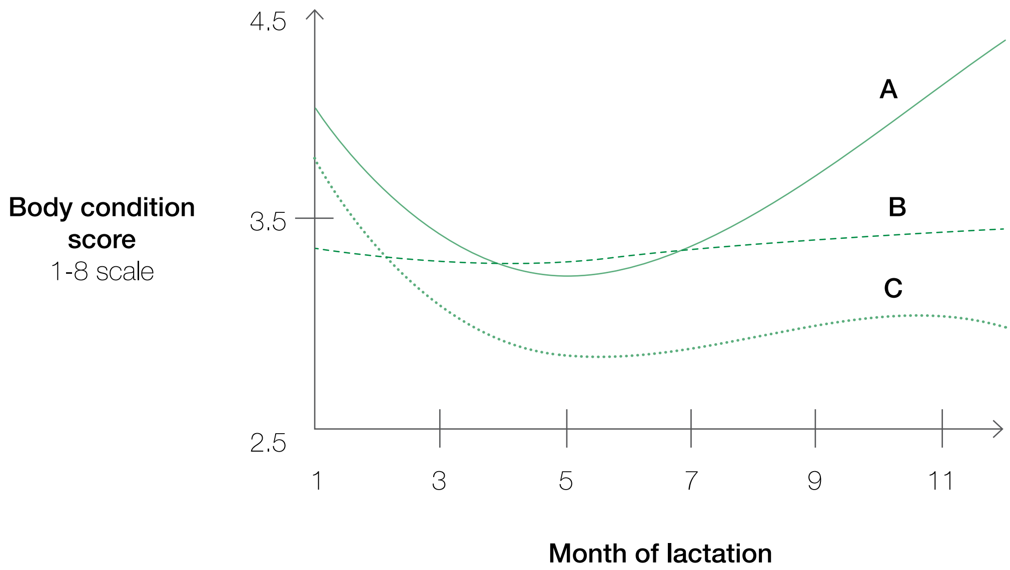
CHANGES IN BCS FOR COWS OF **HIGH** GENETIC MERIT



Source: Adapted from 'Body condition score in dairy cows: targets for production and fertility' 2007, Garnsworthy.

4. Cows do not all follow the same pattern of body condition change in early lactation. There are marked differences among bulls in the shape of their daughters' BCS curves.

CHANGES IN BCS FOR DAUGHTERS OF THREE BULLS



Source: Adapted from Garnsworthy and Wiseman 2006.

5. Calving dates and BCS patterns of cows within a seasonal / split calving system are critical to their reproductive performance.

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	Early lactation	Mid-late lactation	Dry period
Energy balance	Negative then null	Positive	Null or positive

Source: McGill University.

MECHANISMS ASSOCIATED WITH BODY CONDITION CHANGE

Understanding the biological mechanisms associated with changing body condition is critical if accurate judgements are to be made in relation to diet and lactation stage.

Cows are genetically programmed to lose condition at the start of lactation because their bodies prioritise milk production for their calves. Key points to keep in mind include:

- dairy cows lose condition for approximately 40 to 100 days after calving before replenishing lost tissue reserves
- it is not possible to eliminate this loss, so the aim should be to minimise the loss
- it is possible to have an influence on the number of days a cow loses condition for and therefore the total condition loss post-calving

A cow's body condition is not static but changes over the lactation cycle, due to internal biological processes and in response to its feeding regime.

Feed intake lags behind milk production and it can be tricky to ensure that the cow is getting lots of energy per mouthful. Intake is influenced by factors like:

- level of milk production
- amount of feed on offer
- quality of feed
- consistency of ration.

Maximising a cow's feed intake early in lactation produces more milk in the long run.

Post-calving condition loss

40 days ← Aim to be closer to 40 days! **100 days**

NEGATIVE ENERGY BALANCE

In early lactation, no matter how well a cow is fed it will convert (partition) more feed energy into milk than into body condition.

Bring the cow back to positive energy balance sooner with an energy- and protein-dense diet.

BCS and genetic merit

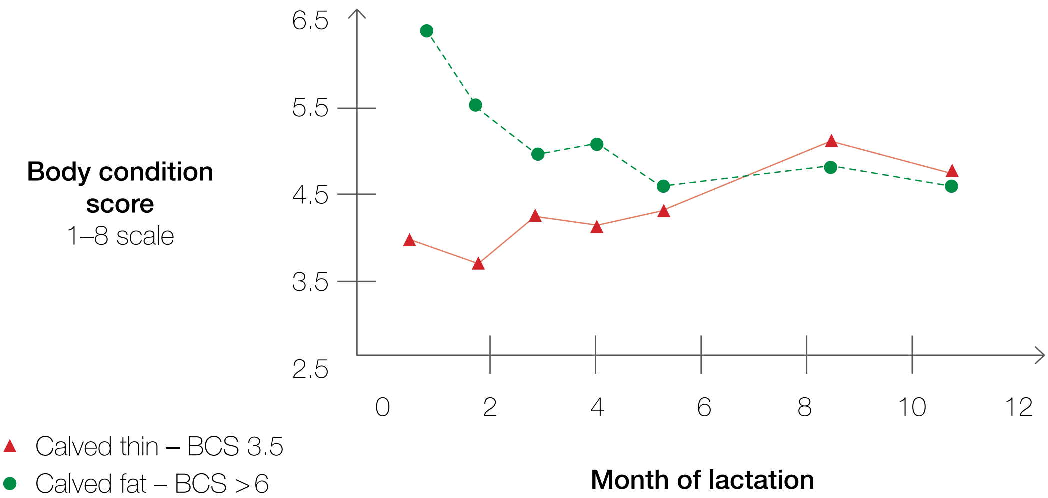
High-genetic-merit cows are generally thinner than low-genetic-merit cows. Regardless of their body condition score at calving, they are genetically programmed to attain a lower condition score at 10–12 weeks into lactation than low-genetic-merit cows.

High-genetic-merit dairy cows selected for increased milk yield are prone to greater insulin resistance, which is associated with greater body lipid mobilisation and a lower drop in body condition score nadir (lowest point).

While largely out of your control in early lactation, it is important to feed as well as possible.

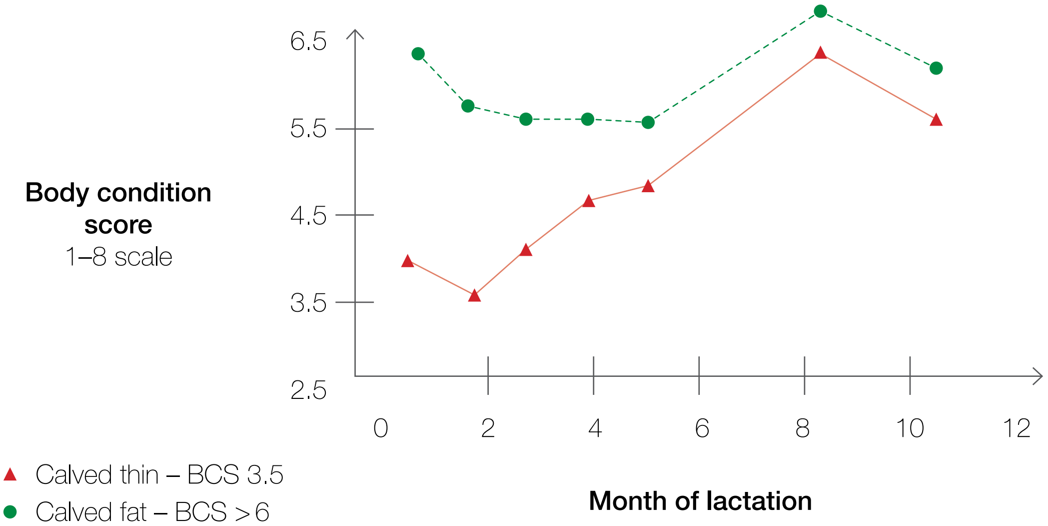
Calving in the target condition score range of 4.5–5.5 will mean the cow gets past the lowest point as quickly as possible.

CHANGES IN BCS FOR COWS OF **HIGH** GENETIC MERIT



Source: Adapted from 'Body condition score in dairy cows: targets for production and fertility' Garnsworthy, 2007.

CHANGES IN BCS FOR COWS OF **LOW** GENETIC MERIT



Source: Adapted from 'Body condition score in dairy cows: targets for production and fertility' Garnsworthy, 2007.

Homeostasis

1. The ability or tendency of an organism or a cell to maintain internal equilibrium by adjusting its physiological processes.
2. The processes used to maintain such bodily equilibrium.

During periods of chronic energy deficit, key hormone expression and tissue responsiveness alter to increase tissue mobilisation and decrease replacement of body reserves. This is known as homeostasis: the tendency of a system to maintain internal stability.

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Adipose tissue (fat) represents the body's predominant energy reserve. Body tissue that is mobilised early in lactation contains a high proportion of fat (lipids) and a low proportion of protein. Nutrients are made available by this process of fat tissue mobilisation and muscle breakdown after calving.

Homeostatic control implies that if the nutritional environment is adequate, the lactating dairy cow can meet its energy demands from dry matter intake, and tissue mobilisation will be minimised.

If homeostatic control was the only regulator of lipid metabolism during early lactation, increased energy intake should, in theory, abolish body lipid mobilisation.

However, attempts to reduce body lipid mobilisation in early lactation (weeks 1–4 post-calving) by feeding energy-rich diets have generally not been successful, and severe feed restrictions during the same period have not always increased tissue mobilisation. This information implies that another mechanism is involved in tissue mobilisation during this early lactation period.

Lipolysis – tissue mobilisation in early lactation, thought to be primarily regulated genetically.

Lipogenesis – replacement of body reserves, thought to be environmentally controlled by diet.

Currently, it is thought that early lactation tissue mobilisation is largely genetically controlled, whereas enzymes involved in improving tissue reserves are primarily regulated by energy intake.

Lipid metabolism is regulated to increase lipid reserves (lipogenesis) during pregnancy and, subsequently, these reserves are utilised (lipolysis) following calving and the initiation of lactation. These changes occur as a function of the cow's stage of lactation rather than as a function of its diet.

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KEY HORMONES

Two hormones that circulate in the cow's blood cause body tissue to be used or stored: growth hormone and insulin.

Growth hormone is a protein hormone released from the anterior pituitary gland. Growth hormone plays a pivotal role in the genetic coordination of body tissue utilisation.

Insulin is a hormone that regulates the replacement of body reserves. Insulin is antagonistic to the tissue mobilisation actions of growth hormone.

As a generalisation, as growth hormone levels change in one direction, insulin levels move in the opposite direction.

	Early dry	**Late dry**	**Early lactation**	**Peak-mid**	**Late lactation**
Physiological state					
Insulin	High	Low	Low	Medium	High
Insulin sensitivity	High	Low	Low	Medium	High
Glucose demand	Low	Medium	High	Medium	Low
Energy partitioning	BC	BC	Milk	Milk	BC

BC = body condition

Source: Dr Mike Allen, Michigan State University.

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Growth hormone

Concentrations of growth hormone level increase at calving, exacerbated by pre-calving energy restriction. Energy is released from adipose fat stores. Growth hormone directly regulates a cow's energy stores by enhancing the response to lipolytic stimuli. Growth hormone inhibits the insulin-mediated uptake of glucose by fat cells.

The net effect of increased growth hormone concentrations is the partitioning of nutrients away from fat cells.

Insulin

Low insulin concentrations and decreased insulin responsiveness of skeletal muscle and adipose tissue occur simultaneously in early lactation. The low insulin concentrations seen in early lactation slowly recover as lactation progresses and milk yields fall.

Insulin also has an important role in preparing mammary tissue for milk production, with plasma insulin concentrations starting to decline a week or two before calving.

INSULIN

Low insulin concentrations and decreased insulin sensitivity in the cow around calving help maintain steady blood glucose levels.

It also helps meet the glucose demands of the developing calf pre-calving and the udder for colostrum and milk production in the first few weeks post-calving.

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Although it does not directly affect the pregnancy rate, the condition score at calving does influence reproduction through its effect on lowest body condition score and body condition loss.

The InCalf project conducted by Dairy Australia clearly showed that body condition at calving was also important for getting cows back in calf.

The project found that the body condition score at calving for the best reproductive performance is 4.5-5.5 on the 1–8 scale.

BODY CONDITION AT CALVING

Body condition score at calving is the most influential point in a cow's lactation cycle. Calving body condition affects:

- early lactation dry matter intake
- post-calving body condition loss
- milk yield
- cow immunity.

The optimum body condition score at calving for reproductive performance is between 4.5 and 5.5.

Thin cows below condition score 4.5:	**Fat cows** above condition score 5.5:
• produce less milk • have an extended post-partum anoestrus interval • are less likely to get pregnant.	• have a reduced DM intake • do not produce any more milk • are more likely to succumb to metabolic disorders around the time of calving.

Calving and early lactation body condition scores outside the optimum range are associated with the incidence of several metabolic disorders (most notably ketosis and milk fever) and also displaced abomasums and probably fatty liver.

For the same period, cows with a high body condition score and excessive tissue mobilisation have an increase in milk fever and ketosis relative to those with a lower body condition score.

Extreme body condition (either too thin or too fat) reflects an increased risk of compromised animal health.

	Early lactation	Mid-late lactation	Dry period
Energy balance	Negative then null	Positive	Null or positive
Milk yield kg/day			

Source: McGill University.

Diet does not greatly influence the rate of body condition loss in very early lactation or the depth of the body condition score drop.

BODY CONDITION IN EARLY LACTATION

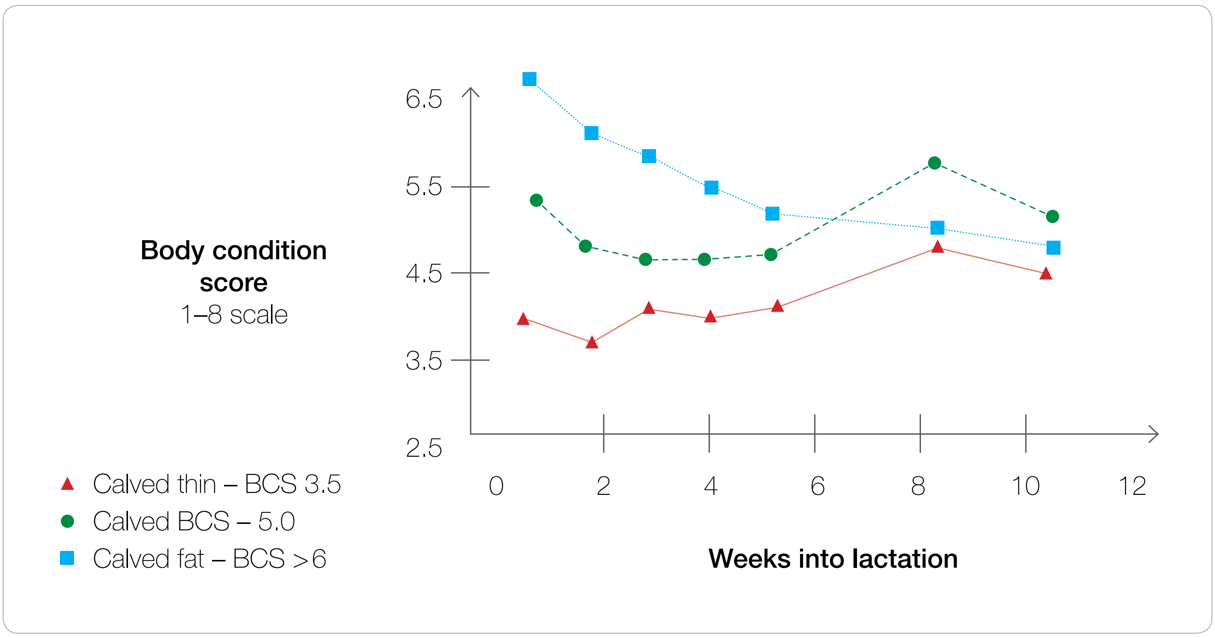
In early lactation, cows are producing lots of milk and the demand for energy increases rapidly. The cow enters a period of negative energy balance because it cannot eat enough to keep pace with the energy demand.

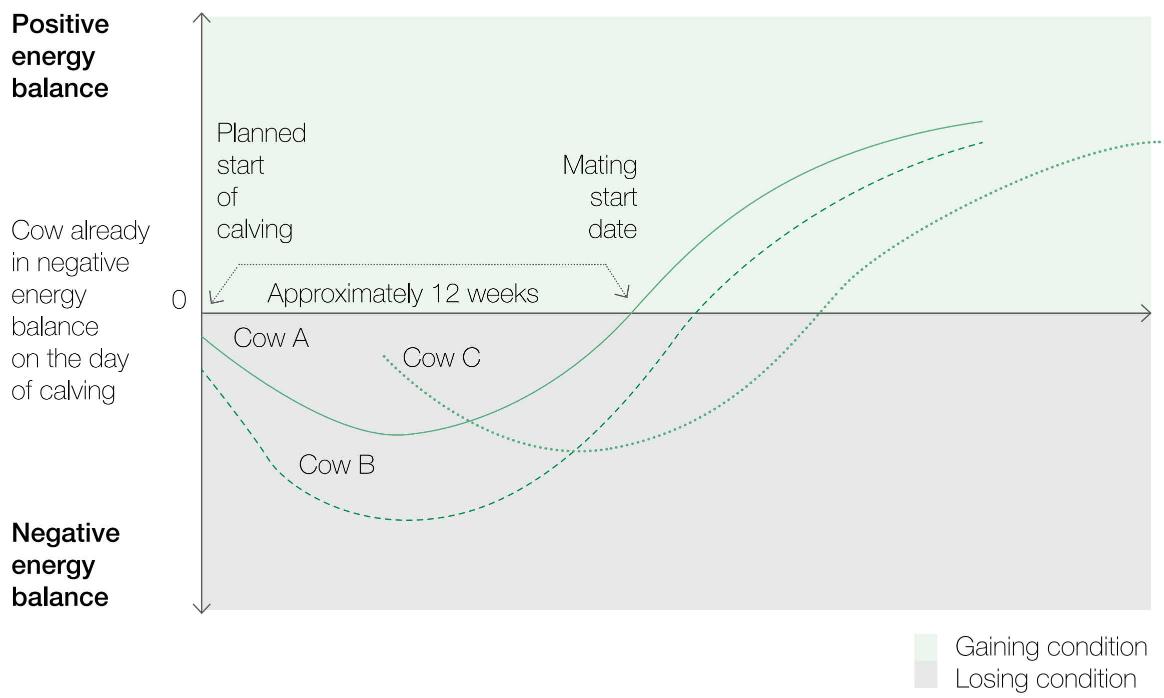
Cows are genetically programmed to peak at a certain milk production level and reach a given BCS at 10–12 weeks into lactation (this is often called 'target BCS'). Higher-genetic-merit cows are thinner animals than lower-genetic-merit cows.

Cows that calve above their BCS target have reduced feed intake after calving and lose condition. Cows that calve below their BCS target have increased feed intake after calving and gain condition.

How deep a cow drops into negative energy balance is more related to feed intake than milk production. The reduction in feed intake pre- and post-calving, and therefore the deepest level of negative energy balance reached in the weeks after calving (i.e. the energy balance nadir) can be minimised through good transition cow management and feeding practices.

The figure below describes the way in which cows with different condition scores at calving might change their condition in early lactation. At calving, the ability of a thin cow to reach its target BCS depends on the quantity and quality of the diet.





Cow A is the ideal cow. She calves early in the calving period in moderate body condition (not too fat or thin for her genetics). Having had a good transition from pregnancy to lactation her post-calving feed intake is reduced but not excessively. She achieves a positive energy balance by the mating start date and is likely to get in calf early in the mating period.

Cow B also calves early in the calving period, but in very high body condition (well above her genetic body condition at 10-12 weeks lactation). Her post-calving feed intake is severely reduced so she drops into much deeper negative energy balance and takes longer than cow A to achieve positive energy balance. She is likely to get pregnant later in the mating period than cow A.

Cow C is very similar to cow A but calves six weeks later. She calves in moderate body condition having had a good transition from pregnancy to lactation. She follows the same energy balance pattern as cow A, but several weeks later. At the mating start date she is at her negative energy balance nadir and unlikely to get pregnant until several weeks later in the mating period.

Use the body condition tools in the *InCalf Herd Assessment Pack* when assessing the cost/benefit of any decisions made to invest to improve BCS due to beneficial fertility and production effects.

Search for *Dairy Australia Herd Assessment Packs.*

BENEFITS FROM ACHIEVING BCS TARGETS

There are reproductive performance and milk production benefits from achieving body condition score targets.

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Reproductive performance

Cows that calve in the BCS range 4.5–5.5 have six-week or 100-day in-calf rates at least 12% higher than if they had calved at a BCS below 4.5.

If you actually had 35% of cows in your herd below BCS 4.5 and 20% above BCS 5.5, the impact on the six-week/100-day in-calf rate would be about 5%. If you achieved a more desirable profile with 10% of cows in the herd below BCS 4.5 and 5% above BCS 5.5, the herd's potential improvement in the six-week/100-day in-calf rate would be 4%.

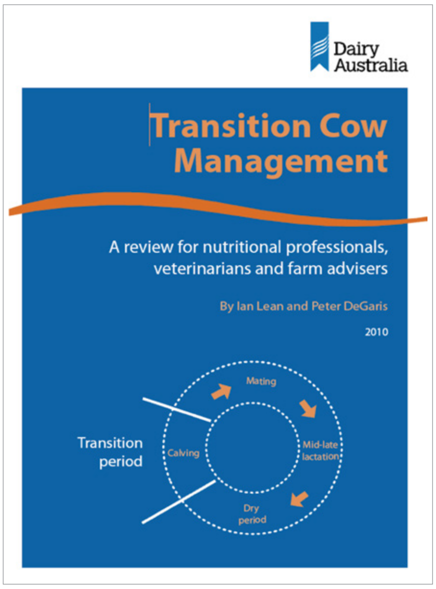
Cows that lose less than one condition score between calving and mating have higher in-calf rates compared to cows with greater losses.

A reduction from a 0.75–1.0 to a 0.45–0.6 average herd BCS change in early lactation could result in a:

- 3% higher six-week/100-day in-calf rate
- 2% lower not-in-calf rate.

Milk production

Each additional condition score at calving up to BCS 5.5 or 6 will result in up to 150 extra litres for the lactation and milk with a higher fat test (while the protein test remains unchanged).



For further information see: Lean I, DeGaris P (2010) Transition cow management – A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

MINIMISE CONDITION LOSS POST-CALVING

To minimise condition loss post-calving, it is important to:

- calve cows down in the body condition score range 4.5–5.5
- feed cows an energy- and protein-dense diet
- manage transition feeding well for good rumen adaption and minimisation of pre-calving dry matter intake drop.

To control body condition score losses **after** calving, make sure the cow is in the optimum condition (4.5–5.5) **before** calving.

LIPOSTATIC THEORY

It is widely accepted that increased cow body condition score is negatively associated with dry matter intake.

Because of this, post-calving body condition loss and the size of the negative energy balance increase with increasing calving body condition score.

However, recent experiments have demonstrated that concentrate feeding in early lactation does not affect the rate of body condition loss in early lactation, but it does reduce the duration of body condition loss (i.e. there are fewer days to the lowest body condition score), thereby slightly increasing the lowest body condition score that a cow will achieve.

Roche JR, Friggens NC, Kay JK, Fisher MW, Stafford KJ, Berry DP (2009) Invited Review: Body condition score and its association with dairy cow productivity, health, and welfare. *Journal of Dairy Science* **92**, 5769–5801.

BODY CONDITION IN MID TO LATE LACTATION & THE DRY PERIOD

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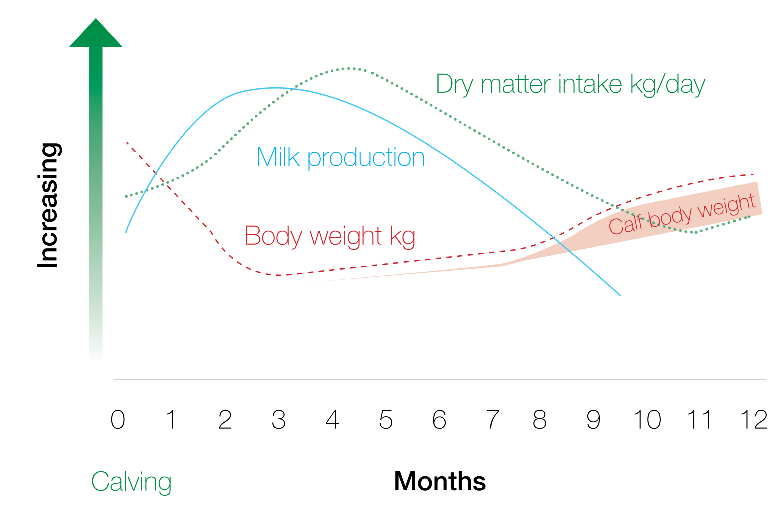
By mid lactation (around 100–200 days after calving), dry matter intake will have peaked and condition loss will have stopped.

The shape of this trend is influenced by how well cows are fed as they progress through lactation.



The dry period may be the only opportunity for cows to put on condition. However, keep in mind that cows use dietary metabolisable energy more efficiently to put on body condition while still milking compared to when dry.

As lactation advances, cows partition increasing amounts of metabolisable energy away from milk production and towards the replenishment of body condition. Cows with high genetic production potential tend to continue partitioning nutrients to milk rather than to body condition during late lactation. They must be fed very well at this time to put on body condition ready for their next calving.

First-calvers, in general, are managed to calve with a greater body condition score than their older herd mates, but they fail to regain body condition as effectively as older cows. A possible reason for this is that first-calvers are still growing.

7

MANAGEMENT OPTIONS

Stage of lactation	What do we want to do?	How do we do it?
3 weeks pre-calving	Adapt rumen to post-calving diet. Minimise dry matter intake drop.	Feed a well-formulated transition diet for at least three weeks pre-calving. The diet should resemble the post-calving diet in terms of ingredients. Minerals and DCAD should be balanced to reduce milk fever and other disorders.
Freshly calved **0–4 weeks post-calving**	1. Overcome negative energy balance: get into true energy balance as soon as possible. 2. Minimise condition loss: reduce number of days losing condition.	1. Calve cows in condition score 4.5–5.5. 2. Feed a transition diet ration three weeks pre-calving. This will: a. eliminate pre-calving negative energy balance b. adapt rumen to post-calving diet c. maximise potential post-calving dry matter intake. 3. Feed an energy- and protein-dense diet post calving.
2nd half of lactation	Increase body condition without compromising milk production.	Feed at higher nutrition than current milk production, to give the cow something left over to go to condition. If a farmer client says, 'She's dropping production, I'll drop her feed back' you need to point out that this may not be the best option. Refocus the client on long-term objectives: a profitable dairy farm is not just about this year, it is about years into the future.

Use the Dairy Australia cow body condition scoring smart phone app and other tools with your clients to monitor and manage herd body condition.

www.dairyaustralia.com.au/BCS

REFERENCES AND FURTHER READING

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8

UNDERSTANDING NUTRITION AND MILK PRODUCTION

The products of digestion provide the building blocks for milk and milk solid production. Blood delivers key substances to the udder:

- glucose from propionate (and also from post-ruminal starch digestion and gluconeogenesis)
- amino acids from microbial protein and undegradable protein (UDP)
- lipids from acetate and fats in the diet.

These substances circulate in the cow's bloodstream ready for their role in the various metabolic processes. Cells in the udder tissue use these to form and secrete milk.

Milk production fluctuates over the lactation cycle. A cow's ability to produce milk depends largely on the interplay between two key factors: feed intake and feed use.

Intake of feed	Carbohydrate, protein and fats from feed are broken down and the products of digestion are absorbed into the blood from the digestive tract.
Use of feed	The products of digestion are used (partitioned) for maintenance, activity, pregnancy, milk production and body condition.

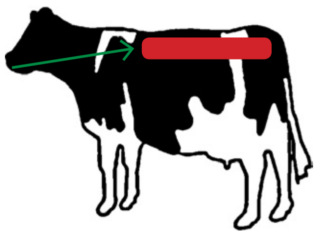
PARTITIONING

Partitioning refers to a cow's internal allocation of feed energy to cover different physiological requirements such as maintenance, activity, pregnancy, milk production or adding fat stores (body condition).

Energy is partitioned differently over the lactation cycle and prioritised according to the needs of the cow and calf. In early lactation, milk production is the priority and a cow will partition energy to this and away from body condition.

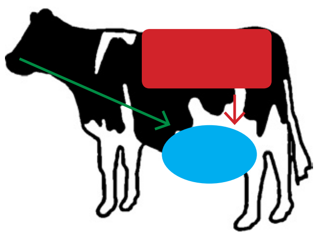
Dry period

Intake goes to body condition
No milk
Body condition increasing



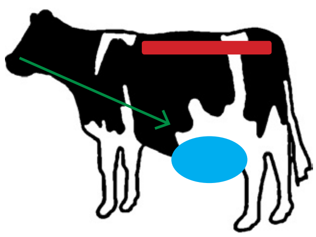
Early lactation

Intake and body condition go to milk
Milk production high
Body condition high but decreasing



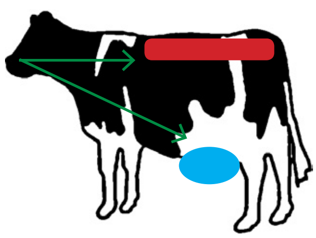
Mid lactation

Intake goes to milk
No body condition to milk
Milk production less-than-peak
Body condition low but steady



Late lactation

Intake goes to body condition and milk
No body condition to milk
Milk production less-than-peak
Body condition low but steady



Intake Body condition Milk

Source: developed by Frank Tyndall.

MILK COMPOSITION

Milk has five key components: water, lactose, milk fat, milk protein and minerals.

- Water is derived from water in the blood.
- Lactose is derived from propionate and other source which produce glucose.
- Milk fat – lipids are derived from acetate, fats in the diet and released body fat.
- Milk protein (mainly in the form of casein) is built from amino acids.
- Minerals, which must be supplied directly through the diet as they are not synthesised through the body.

8

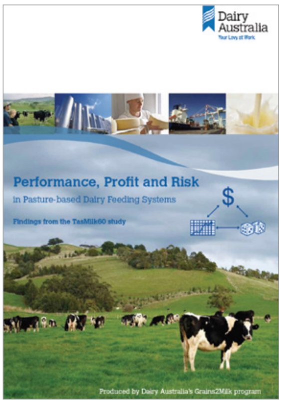
Of these components, fat and protein are the most variable and valuable. In general, dairy farmers are paid for fat and protein (milk solids), with a penalty for volume.

Milk solids				
Fat	Protein	Water	Lactose	Minerals
Jersey 4.9–5.3% Friesian 3.7–4.3%	Jersey 3.6–3.9% Friesian 3.1–3.4%	85.5–87.7%	4.8–5.0%	0.7–0.8%
variable		**relatively constant**		

While milk fat and protein percentages can alter as a result of diet, it is important to remember that nutrition is only one factor that influences the production of milk and its components.

The concentrations of fat and protein and the volume of milk produced vary depending on the breed of cow, stage of lactation and diet.

For further information search for *Performance, profit and risk in pasture-based dairy feeding systems – Findings from the TasMilk60 study*.



NUTRITIONAL DRIVERS OF MILK COMPOSITION

The quantity of glucose arriving at the udder determines how much lactose is produced.

Lactose drives the volume of milk production. The quantity of lactose produced is driven by the amount of propionate available. Propionate is an end-product of fermentation of starch and sugars and pectin.

Fibre intake produces acetate, which drives milk fat content.

Energy intake drives milk protein content.

Protein and lactose (which drive milk volume) are related: as one goes up, so does the other. This keeps protein concentration fairly constant.

If milk composition is changed, the dollar value of a kg of milk solids (kg protein and kg fat) is changed too. Milk that has a higher protein to fat ratio (e.g. 1.0:1.0) will have a higher value per kg milk solids than milk with a ratio of 1.0:1.3.

As shown in the TasMilk60 study (2011), the average kg of milk solids can vary significantly in protein to fat ratio from farm to farm. Protein to fat ratios were higher on farms where more concentrates were fed and milk production per cow was higher, largely due to the reduced fat concentrations in milk from those farms.

BIOCHEMISTRY BASICS

Lactose is a *disaccharide* – a sugar composed of glucose and galactose.

Glucose and galactose are *monosaccharides* or simple sugars. Monosaccharides are the simplest form of carbohydrate and cannot be broken down further.

Glucose is the main source of energy of living things and is produced in plants via photosynthesis. Plants store excess glucose as starch. Starches are *polysaccharides* – complex carbohydrates made of chains of simple sugars.

Animals store any excess of glucose they may produce as a result of their diet as glycogen.

When an animal needs extra energy, its blood glucose level drops. This drop triggers glycogen to be broken down into glucose by a hormone called glucagon. This results in more glucose entering the bloodstream.

If too much glucose is present in the bloodstream, the hormone insulin is released.

BIOCHEMISTRY BASICS

Insulin lowers blood glucose levels.

Glucagon = blood glucose up.

Insulin = blood glucose down.

VOLUME AND LACTOSE PRODUCTION

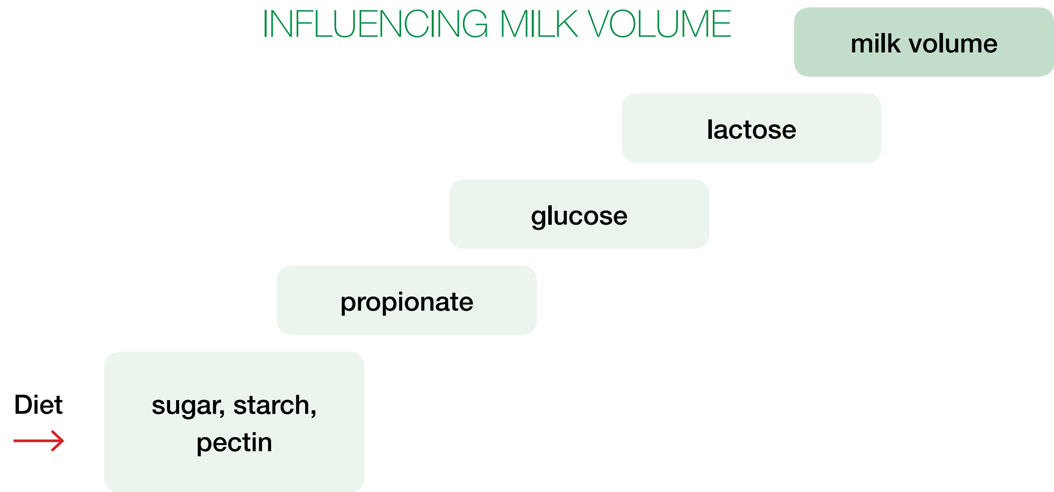
The udder makes lactose from the simple sugar glucose arriving in the blood.

The lactose secreted into the udder attracts water with it, in roughly constant proportions. Therefore, the lactose content of milk does not change much. It usually stays at about 4.8–5.0%, although this does vary to some degree with breed.

Thus, the quantity of glucose arriving at the udder determines how much lactose is produced and this drives the volume of milk production.

The quantity of lactose produced is driven by the amount of propionate available. Propionate is an end-product of fermentation of starch and sugars and pectin.

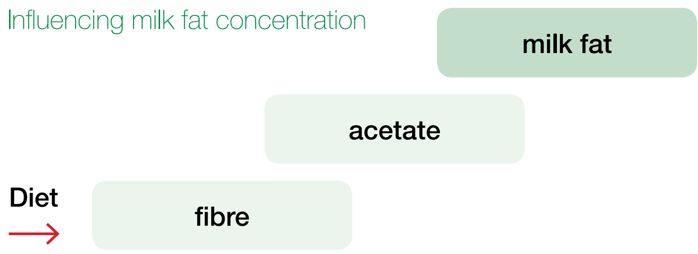
INFLUENCING MILK VOLUME



MILK FAT PRODUCTION

The udder makes milk fat from:

- lipids carried in the blood; the blood lipids come from body fat released as a cow looses body condition
- acetate produced by rumen microbes, mainly from fibre in the diet.



Influencing milk fat concentration

MILK FAT CONCENTRATION

Milk fat concentration varies greatly, depending on the interplay of four key drivers:

- the type of energy in the diet
- energy intake
- stage of lactation
- body condition of the cow.

Harvatine and Bauman review two key questions related to milk fat depression: 1. How quickly is milk fat synthesis decreased during milk fat depression? and 2. Does milk fat depression alter the energy balance of a lactating dairy cow? See below.

Biohydrogenation

The products of incomplete biohydrogenation of dietary fats (i.e. trans-10 isomers of conjugated linoleic acid CLA) cannot be used by the udder to synthesise milk fat.

Therefore, milk fat concentration is depressed.

For information on the biohydrogenation process see http://ansci.cornell.edu/bauman/cla/rumen_metabolism/index.html.

MILK FAT CONCENTRATION – INTERPLAY OF FOUR KEY DRIVERS

Type of energy in diet Fibre promotes milk fat concentration	**Energy intake** Milk fat concentration is lower if energy intake is high
• Fibre breaks down to acetate. • Acetate enters the bloodstream. • Acetate is used for milk fat synthesis. • Incomplete biohydrogenation of excessive dietary polyunsaturated fatty acids by the rumen microbes will result in milk fat depression.	• If energy intake is high, rumen fermentation is also high. Rumen is more acidic which favours starch-digesting microbes that produce propionate. Rumen is less suitable for fibre digesting microbes to produce acetate. • Milk fat production is driven by acetate from fibre digestion.
Stage of lactation High milk volume dilutes milk fat concentration	**Body condition** Milk fat concentration will be higher if the cow is losing condition
• Milk fat concentration is likely to be lower in peak lactation when milk volume is at its highest.	• The cow uses the energy that body condition loss generates for milk fat production. • Body condition loss in early lactation may help maintain milk fat concentration as yield increases.

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See Harvatine KJ, Bauman DE (2007) Recent advances in milk fat depression: 1. Time course of milk fat depression and 2. Adipose tissue lipogenesis during milk fat depression; search for *Recent advances in milk fat depression*.

MILK FAT DEPRESSION: NEW THINKING ON THE CAUSES

Traditionally, high cereal grain diets, through a lack of dietary fibre, have been blamed for depressions in milk fat concentrations (e.g. Sutton et al. 1988).

One of the key theories put forward to explain milk fat depression has revolved around an increase in glucogenic precursors in the rumen such as propionate, and a decrease in lipogenic precursors such as acetate and butyrate, due to changes in rumen fermentation.

Under normal conditions, the lipogenic/glucogenic ratio of volatile fatty acids in rumen fluid would be 4:1 or better, with the underlying factor of most importance in the maintenance of this ratio being the roughage content of the diet. As dietary NDF falls, the volatile fatty acid ratio would also decline, along with milk fat concentration.

There is an increasing body of evidence that has given rise to a new theory for milk fat depression, the biohydrogenation theory.

This theory suggests that biohydrogenation of dietary polyunsaturated fatty acids, principally linoleic acid, by ruminal bacteria is more likely to be responsible for milk fat depression than the more traditional glucogenic theory (e.g. Bauman and Griinari 2001, 2003).

With this theory, two following conditions are required for milk fat depression to occur.

1. The presence of polyunsaturated fatty acids – e.g. from high-quality pasture
   Alterations in rumen activity involve both the microbial fermentation of dietary carbohydrates and the microbial biohydrogenation of fatty acids.
2. An alteration in rumen microbial processes
   High-grain/low-roughage diets are associated with low rumen pH, changes to the microbial population and high outflow rates of rumen fluid and digesta, even to the extent of subacute rumen acidosis occurring. When diets that are low in fibre are supplemented with plant oils, thereby providing plenty of polyunsaturated fatty acids, there is ample opportunity for some of the lipid to escape full biohydrogenation because of the rate of outflow from the rumen.

The pathway for biohydrogenation of fats during normal ruminal fermentation is for linoleic acid to be fully biohydrogenated to stearic acid via the intermediary cis-9, trans-11 conjugated linoleic acid (rumenic acid).

During altered ruminal fermentation, other minor CLA forms can become more dominant, particularly the trans-10 CLA isomers.

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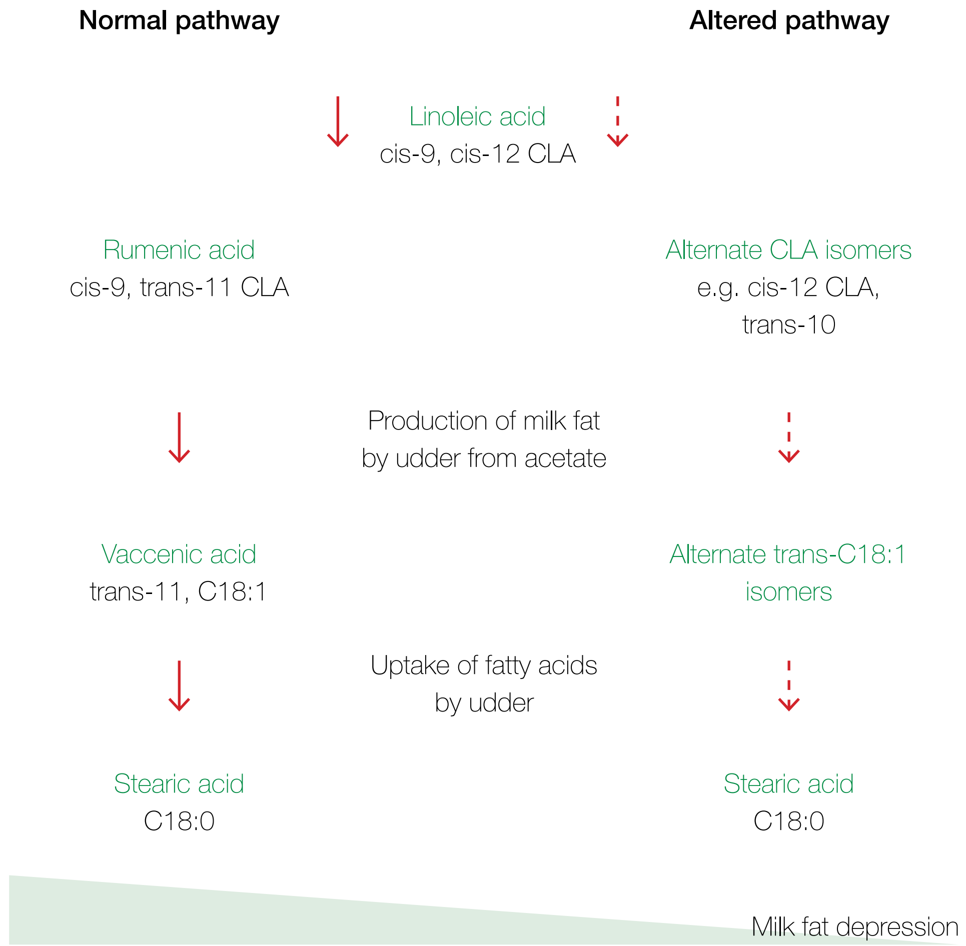
BIOHYDROGENATION PATHWAYS DURING NORMAL & ALTERED RUMINAL FERMENTATION



Source Adapted from Harvatine KJ, Bauman DE (2007) Recent advances in milk fat depression: 1. Time course of milk fat depression and 2. Adipose tissue lipogenesis during milk fat depression: Cornell University.

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Baumgard et al. (2000) have shown that 3.5 g/day of trans-10, cis-12 CLA causes a 25% reduction in milk fat concentration. Conversely, if the oils are completely hydrogenated or they bypass the rumen microbes because they are fed in a rumen-protected form, there are minimal effects on milk fat.

All of this means that low fibre per se may not be the only, or even the major, factor causing low milk fat concentrations. However, although milk fat depression may have little to do with fibre insufficiency, the lack of fibre does result in rumen conditions that affect the biohydrogenation of dietary fatty acids, which could be the real culprit.

Importantly however, there must be reasonable quantities of polyunsaturated fatty acids in the diet in the first instance for partial biohydrogenation to result in the unique fatty acid intermediates that inhibit milk fat synthesis in the mammary gland.

BIOCHEMISTRY BASICS

Protein molecules are made up of amino acids.

Amino acids are the building blocks of proteins. There are over 100 amino acids occurring naturally and of these, 20 make up protein.

Some amino acids are categorised as essential. Essential amino acids must come from dietary sources.

Non-essential amino acids are synthesised in the body.

MILK PROTEIN PRODUCTION

Milk protein (mainly in the form of casein) is built from amino acids. These amino acids are derived from microbial protein and undegradable protein (UDP). Glucose is used as the energy source for this building process.

Sometimes, although the supply of amino acids to the udder is plentiful, there is not enough glucose energy available to build them into milk protein. In this case, some of the amino acids are converted to glucose and used to provide energy. This is not an efficient use of nutrients because it wastes the protein-producing potential of the amino acids.

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If glucose is plentiful but amino acids are in short supply, the building of milk protein will be limited. Amino acids can be metabolised to glucose if there is a shortage of glucose, but the reverse cannot occur. The surplus glucose may produce some lactose but most will be stored and the cow will put on body condition rather than produce milk. This is also a less efficient use of feed.

Milk protein and lactose production (and therefore milk volume) follow the same trends because:

- glucose in the blood is needed to produce both lactose and protein
- the quantity of amino acids and the amount of glucose in the blood for protein and lactose production tend to be related to each other, due to diet.

The udder makes milk protein from the amino acids and glucose carried in the blood.

Amino acids are the building blocks, and the glucose provides the energy to do the building.

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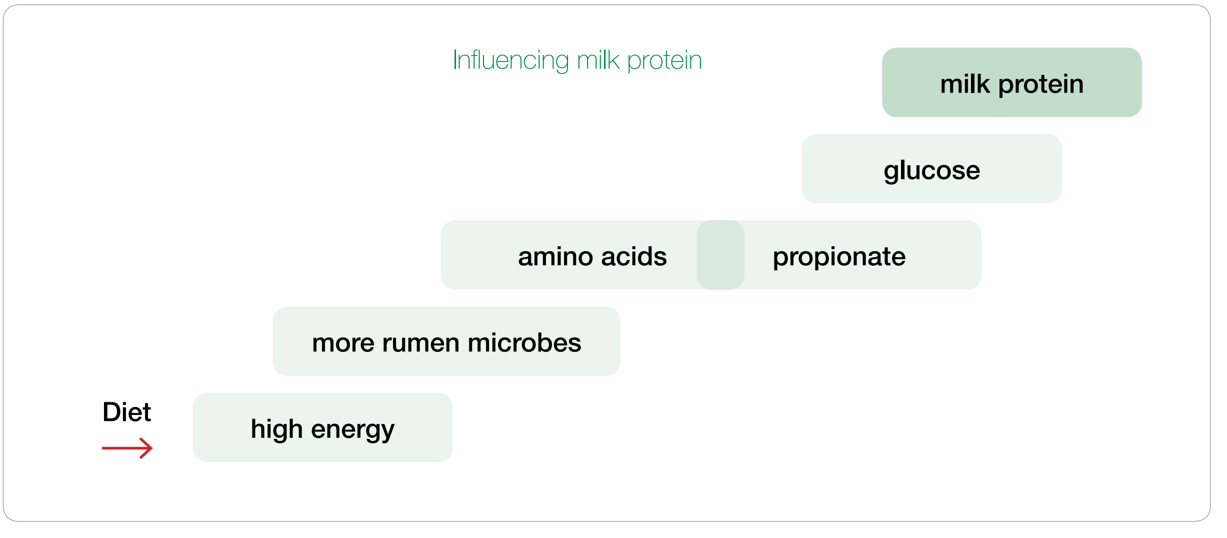
INFLUENCING MILK PROTEIN

The difficulty in shifting milk protein concentration arises because protein and lactose productions are related. As one goes up so does the other, thereby keeping protein concentration fairly constant.

A diet higher in energy often produces more rumen microbes, which are digested to amino acids. A high-energy diet also produces more propionate, which converts to glucose.

Increasing energy intake with glucose increases milk protein concentration, but only to a small degree.



Keep in mind that the milk protein response is not entirely about what happens to dietary energy in the rumen.

Feeding bypass starch (aimed at digestion in the small intestine and absorbed directly as glucose) can provide some additional glucose to help boost milk and protein responses in the udder.

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9

FEED REQUIREMENTS IN DRY PERIOD

The dry period is considered to consist of:

- **the early or far-off dry period, from 8 to about 3 weeks pre-calving**
- **the pre-calving transition period, which includes the 3–4 weeks just before calving. It is often called the close up or late dry period.**

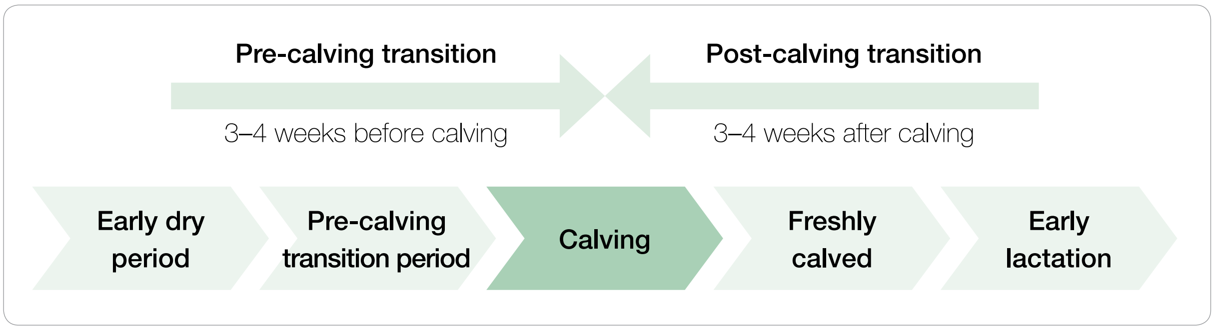
The post-calving transition period includes the 3–4 weeks immediately after calving.

The dry period of dairy cows has frequently been characterised as the time of lowest nutritional requirements, or as a resting phase in which the cow prepares for the next lactation. This has given some people the impression that this period is less important than other parts of the lactation cycle. In fact, the dry cow's body is undergoing many essential processes during this period in preparation for the next lactation.

The dry period, and in particular the late dry period, should be considered a critical time because the quantity and quality of all feed inputs will directly impact on:

- the incidence of cow health problems associated with calving
- the productive performance in the next lactation.

It may also influence the reproductive performance at the next joining.



THE EARLY DRY PERIOD

Drying off occurs when milk is not removed from the udder for an extended period. As a consequence, resulting pressure causes the milk glands to stop producing milk.

Ideally, cows should be dried off in the condition that they are expected to calve in, so that they only need to be fed to maintain body condition through the dry period.

It is more efficient to manipulate body condition while cows are still milking, but this may not always be possible.

Often, a number of cows finish lactation underconditioned in spite of the farmer's best efforts. These cows need differential feeding in the early dry period.

At this stage, the aim for fat cows (BCS over 6) should be to maintain body condition rather than to attempt to reduce it.

Fat cows are often low-producing cows, so culling could be considered.

For further information see Chs 16, 17, 18, 19 and 20.

PUTTING ON CONDITION IN THE EARLY DRY PERIOD

If body condition needs improving after dry-off, it should happen before the last month of gestation. In the last 3–4 weeks before calving, a cow will struggle to eat enough to maintain basic functions, provide for the foetus and improve body condition at the same time.

The early dry period is the last opportunity to improve the body condition before calving.

ADVISER ALERT

The quality of forages fed through the early dry period is very important, but too often low-quality hay is fed.

If condition needs improving in the early dry period, consider energy-dense, protein-rich feeds.

LACTATION DRIVES APPETITE: DRY COWS EAT LESS

A cow's appetite is reduced during the dry period. This fact, combined with a high-fibre diet, means intakes in the early dry period are restricted to around 2% of live weight per day: that is, a maximum of 11 kg DM for a 550 kg cow.

An example

Two months from calving, a 550 kg cow requires around 90–100 MJ ME per day and a diet with at least 12% CP.

Feeding poor-quality hay (8 MJ ME, 10% CP/kg DM) means that the cow would need to eat 12.5 kg DM of that hay to meet its energy needs, and would not meet the requirement for protein.

Poor-quality hay normally has a high lignin content which requires lots of chewing to break it down. This leads to slow passage at times.

As a result, the cow would probably only be able to eat about 9–10 kg of this type of hay. This would lead to condition loss as the cow uses its reserves to meet the increasing needs of the foetus.

Dry cows eat less kg DM per day than lactating cows.

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BODY CONDITION SCORING IN PRE-CALVING TRANSITION

As the dry period progresses, it can be difficult to assess the real condition score of a cow due to weight gains associated with foetal growth. When calving is imminent, relaxation of muscles make condition scoring less meaningful.

FEED REQUIREMENTS IN THE PRE-CALVING TRANSITION PERIOD

The most important time of a cow's lactation cycle is the transition period, a period 3–4 weeks either side of calving.

The pre-calving transition period is a time when the cow undergoes a series of metabolic changes that allow its body to adapt to the challenges of lactation.

Nutrients are required to support growth and maintain the foetus, placenta, uterus and mammary gland.

Intake at calving and intake in early lactation are linked. Cows that eat well in early lactation go on to be more productive later in the lactation.

Pre-calving transition diets should introduce feeds the cow will encounter post-calving.

Low intake results in the mobilisation of body tissue. Excessive fat mobilisation can cause disorders such as ketosis.

Although cows have plenty of calcium stored in their bones, they need at least one week to begin the mobilisation process. Any deficit increases calcium absorption from the intestine. If blood calcium drops, milk fever results.

Other cow health problems related to low blood calcium levels (hypocalcaemia) around calving include:

- ketosis
- retained foetal membranes
- metritis
- mastitis
- displaced abomasum
- calving difficulties.

Minimising the decline in intake as calving approaches and limiting the risk of disorders, particularly milk fever, are two of the key objectives of feeding during the last few weeks of gestation.

PRE-CALVING TRANSITION DIETS

An effective transition diet aims to

1. meet the cow's growing demand for energy and protein
2. maintain dry matter intakes
3. adapt the rumen to the post-calving diet
4. minimise the risk of milk fever and other health problems
5. minimise mobilisation of body tissue and associated excess fat mobilisation disorders.

If these five aims are achieved the benefits are considerable and include:

- the cow being set up for a productive lactation
- almost no clinical cases of milk fever in the herd
- very low incidence of other health problems common soon after calving
- reduced death and culling rates around calving
- improved herd reproductive performance
- less labour and stress spent on sick cows
- improved animal welfare.

Depending on the approach used, a three week pre-calving transition feeding program could return a net benefit of $200+ per cow. This depends on the extent to which the diet addresses the nutrition needs of the transition cow.

See p. 9.13 for a table of nutritional recommendations for a fully integrated transition diet pre-calving. For further information, see Ch 21.

MINERAL REQUIREMENTS IN TRANSITION

Calcium, magnesium, phosphorus and DCAD (K, Na, S, Cl) in the diet all independently influence milk fever risk. The recommended target for a herd's milk fever is <1%.

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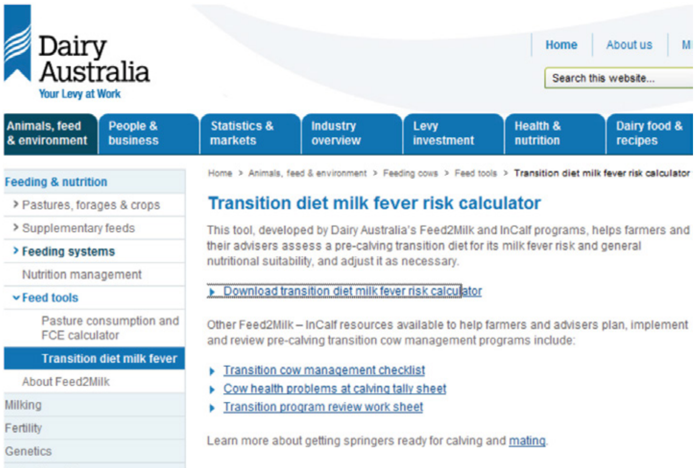
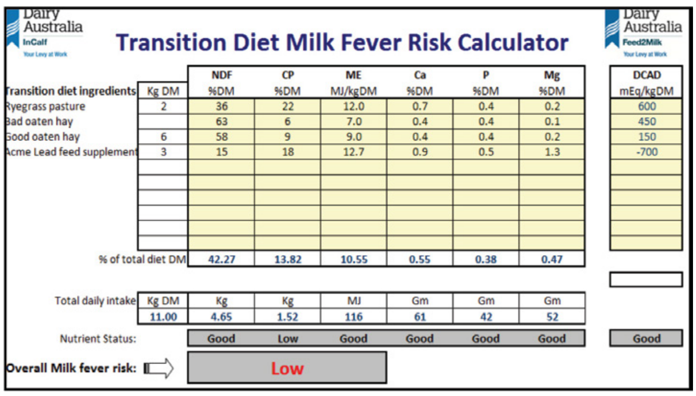
To calculate calcium, magnesium, phosphorus and DCAD levels in the transition diet it is important to have all components of the diet analysed.

All major feed testing laboratories now have a standard transition testing package available that includes wet chemistry testing of mineral content.

A spreadsheet calculator is available to assist with transition diet balancing at www.dairyaustralia.com.au.




Dairy Australia InCalf Your Levy at Work — **Transition Diet Milk Fever Risk Calculator** — Dairy Australia Feed2Milk Your Levy at Work

Transition diet ingredients	Kg DM	NDF %DM	CP %DM	ME MJ/kgDM	Ca %DM	P %DM	Mg %DM	DCAD mEq/kgDM
Ryegrass pasture	2	36	22	12.0	0.7	0.4	0.2	600
Bad oaten hay		63	6	7.0	0.4	0.4	0.1	450
Good oaten hay	6	58	9	9.0	0.4	0.4	0.2	150
Acme Lead feed supplement	3	15	18	12.7	0.9	0.5	1.3	-700
% of total diet DM		42.27	13.82	10.55	0.55	0.38	0.47	
Total daily intake	Kg DM	Kg	Kg	MJ	Gm	Gm	Gm	
	11.00	4.65	1.52	116	61	42	52	
Nutrient Status:		Good	Low	Good	Good	Good	Good	Good
Overall Milk fever risk:		Low						

ADVISER ALERT

Beware that older references recommend intermediate dietary calcium levels (such as 1–1.5%).

In pasture-based feeding systems, calcium concentration in the total pre-calving transition diet should be controlled to around 0.4% to 0.6% (DM).

To achieve a low incidence of milk fever, feed either very low or very high levels of calcium in the pre-calving transition diet.

Feeding low levels of calcium is easier, more practical and more certain.

TRANSITION DIET: CALCIUM

Calcium is so essential to the function of the body that concentrations in blood must be kept within a tight range.

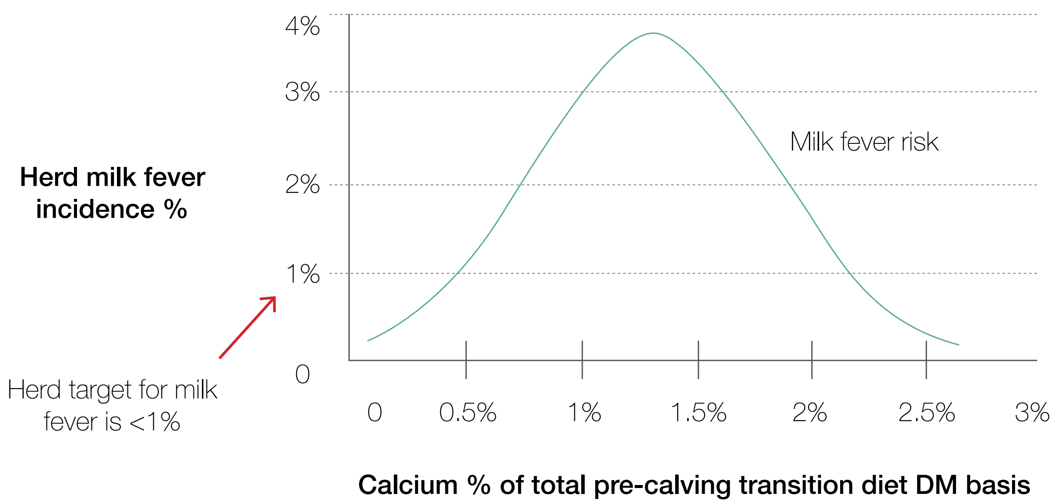
The cow's body has a finely tuned system of homeostasis to maintain concentrations in a tight range. Large and sudden changes in calcium requirement with the onset of lactation present a big challenge to these homeostatic systems.

Control of calcium, magnesium, phosphorus and DCAD (K, Na, S, Cl) in the diet can assist the operation of these homeostatic systems, and all independently influence milk fever risk.

Restricting calcium intake prior to calving encourages the activation of the systems to mobilise calcium from bone stores.

The figure below demonstrates that a lower dietary calcium concentration in the transition diet pre-calving lowers the risk of milk fever than does higher concentrations.

EFFECT OF CALCIUM ON MILK FEVER RISK



Source: Adapted from Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

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RECOMMENDATION:

Magnesium concentration in the total pre-calving transition diet should be at least 0.45% (DM).

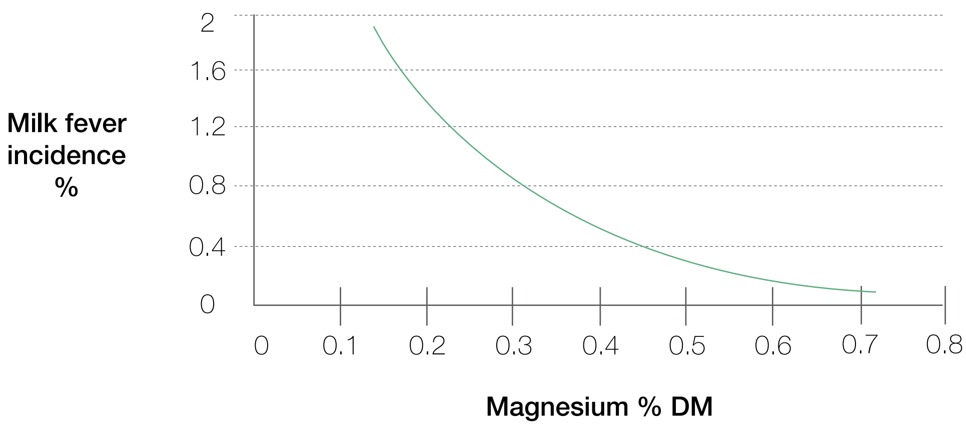
TRANSITION DIET: MAGNESIUM

Magnesium plays many important roles in the body, including calcium homeostasis.

Magnesium is critical in the release of parathyroid hormone and in the synthesis of active Vitamin D3.

Increased levels of magnesium in the pre-calving transition diet carry a reduced milk fever risk.

EFFECT OF MAGNESIUM ON MILK FEVER RISK



Source: Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

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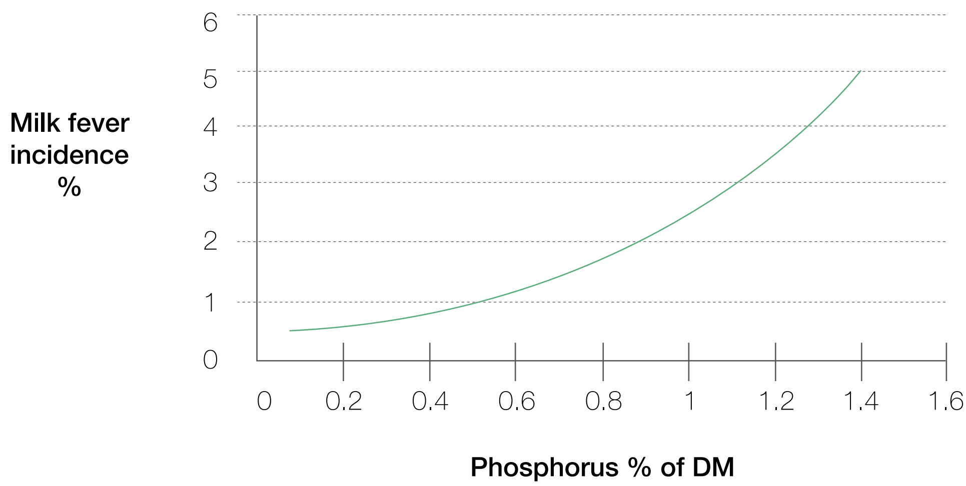
RECOMMENDATION:

Phosphorus concentration in the total pre-calving transition diet should be controlled to less than 0.4% (DM).

TRANSITION DIET: PHOSPHORUS

Increased levels of phosphorus in the pre-calving transition diet carry an increased milk fever risk.

EFFECT OF PHOSPHORUS ON MILK FEVER RISK



Source: Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

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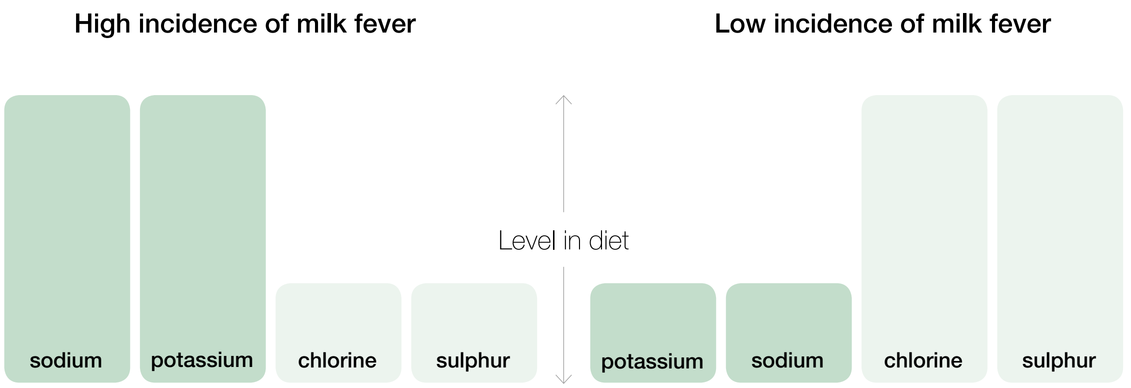
TRANSITION DIET: DIETARY CATION-ANION DIFFERENCE

To understand the role that dietary cation-anion difference (DCAD) plays in the transition diet, note the following.

- Diets high in sodium and potassium (cations) and low in chlorine and sulphur (anions) increase the risk of milk fever.
- Diets high in chlorine and sulphur and low in sodium and potassium, through the use of carefully chosen feed ingredients and anionic feed supplements such as anionic salts, decrease the risk of milk fever.
- The physiology of the DCAD theory of milk fever control has its basis in the strong ion model of acid/base balance.
- The feeding of anionic salts appears to act to increase mobilisation of calcium from bone, allow loss of urinary calcium and increase absorption of dietary calcium.



Source: Adapted from Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

Many equations have been proposed for calculating the DCAD of diets. The following equation has been adopted as the most appropriate DCAD equation to predict the effect of a diet on the risk of milk fever:

DCAD (mEq/kg) = $(Na^+ + K^+) - (Cl^- + S^{2-})$

Feed analysis laboratories have now adopted this equation as the industry standard and express results in mEq/kg dry matter.

RECOMMENDATION:

The target DCAD of the transition diet is 80 mEq/kg DM or less.

The aim of DCAD manipulation of pre-calving diets should be to reduce milk fever risk, not to manipulate blood or urine pH.

Urine pH is a relatively insensitive indicator of DCAD and is therefore no longer recommended as a tool to monitor efficacy of dietary acidification.

Any decrease in DCAD results in a reduction in milk fever risk, even if zero mEq/kg is not achieved.

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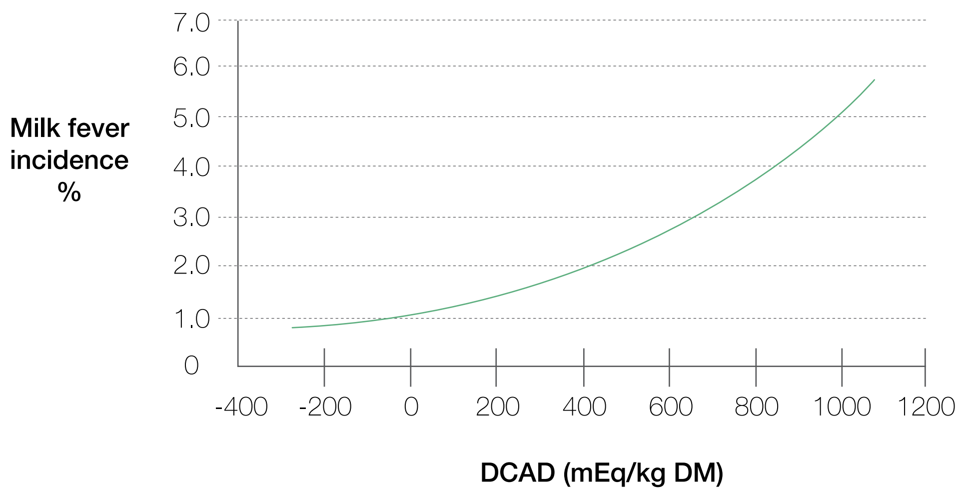
RELATIONSHIP BETWEEN DCAD AND MILK FEVER RISK



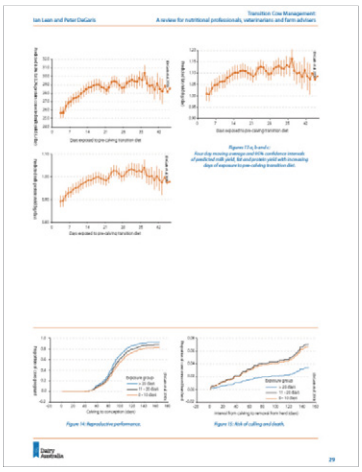
Source: Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

Achieving a dietary DCAD near target can be very difficult if a large amount of pasture is included in the diet.

Pasture, pasture hay and silage often have very high potassium concentrations (due to the top-dressing of pastures with potassium fertilisers) and therefore high DCADs.

The only way to be certain that forages are suitable for use in pre-calving transition diets, having appropriate calcium, magnesium, phosphorus and DCAD levels, is to have them analysed at a feed testing laboratory.

For further information, see p. 29 of Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.



LENGTH OF EXPOSURE TO PRE-CALVING TRANSITION DIET

The optimal length of exposure to a pre-calving transition diet is about three weeks in terms of:

- milk fat and protein yields over the lactation
- better fertility
- increased longevity in the herd.

Pregnancy testing by a skilled operator between 5–15 weeks of gestation is the best way to get accurate conception and due calving dates.

Nutritional recommendations for a fully integrated transition diet pre-calving for early dry cows, pre-calving transition cows and fresh cows			
Nutrient	**Total diet analysis (dry matter base)**		
	Early dry cows (More than four weeks pre-calving)	**Transition cows (Last four weeks pre-calving)**	Fresh cows (First four weeks post-calving)
Neutral detergent fibre % (NDF)	>36%	**>36%**	>32%
Physically effective NDF %	30%	**25–30%**	>19%
Crude protein (CP) %	>12%	**14–16%**	16–19%
Degradability of CP	80%	**65–70%**	65–70%
Metabolisable energy intake per day (MJ)	90–100	**100–120**	160
Estimated energy density (MJ ME / kg DM)	10 (9)*	**11**	11.5–12
Starch %	Up to 18%	**18–22**	22–24
Sugar %	Up to 4%	**4–6**	6–8
Fat %	3%	**4–5%**	4–5%
Calcium %	0.4%	**0.4–0.6%**	0.8–1.0%
Phosphorus %	0.25%	**0.25–0.4%**	0.4%
Magnesium %	0.3%	**0.45%**	0.3%
DCAD^ Meq/kg	<150	**<80**	>250
Selenium mg/kg	0.3	**0.3**	0.3
Copper mg/kg	10	**15**	20
Cobalt mg/kg	0.11	**0.11**	0.11
Zinc mg/kg	40	**48**	48
Manganese mg/kg	12	**15**	15
Iodine mg/kg	0.6	**0.6**	0.6
Vitamin A iu/g	2000	**3200**	3200
Vitamin D iu/g	1000	**#**	1000
Vitamin E iu/g	15	**30#**	15

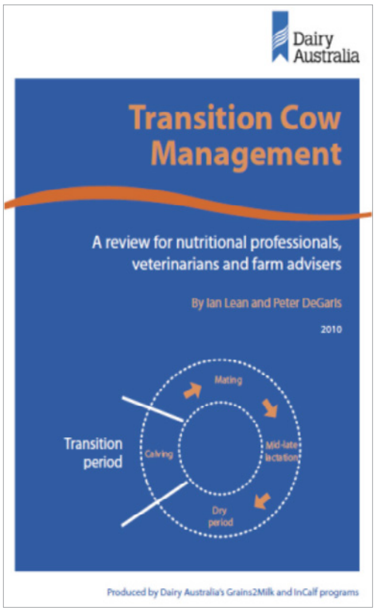
*Energy content that is desirable will vary with body condition

^ See section 4 for details

Vitamin D and E concentrations in the transition period are yet to be determined. Vitamin D inputs, in particular, will be determined by new understandings of the use of this vitamin to prevent milk fever.

Source: Lean I, DeGaris P (2010) Transition cow management: A review for nutritional professionals, veterinarians and farm advisers. Dairy Australia.

Key resource: Lean I, DeGaris P (2010) *Transition cow management: A review for nutritional professionals, veterinarians and farm advisers* (Eds. Little S, Penry J). Dairy Australia.



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10 FEED REQUIREMENTS DURING LACTATION

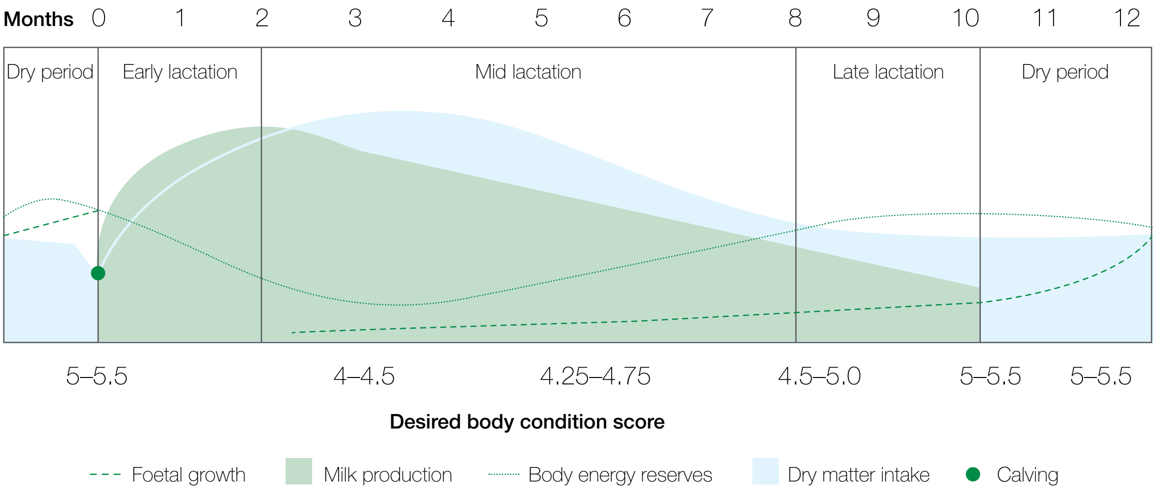
Every day, cows need about the same amount of energy and protein for maintenance but requirements for production vary greatly throughout the lactation cycle.

No matter what the stage of lactation, cows have basic needs. Every day, cows need a set amount of energy and protein for maintenance of their basic bodily functions.

Feed intake, body condition and milk production all fluctuate over the lactation cycle.

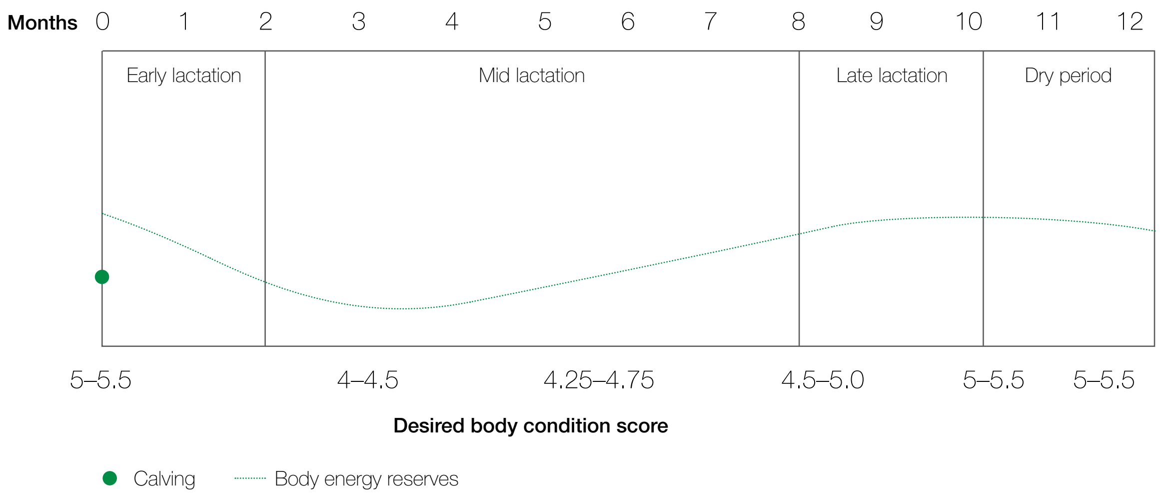
Understanding the interplay between changing intake, body condition and milk production is critical when making nutrition recommendations.

COW BODY CONDITION, FEED INTAKE AND MILK PRODUCTION

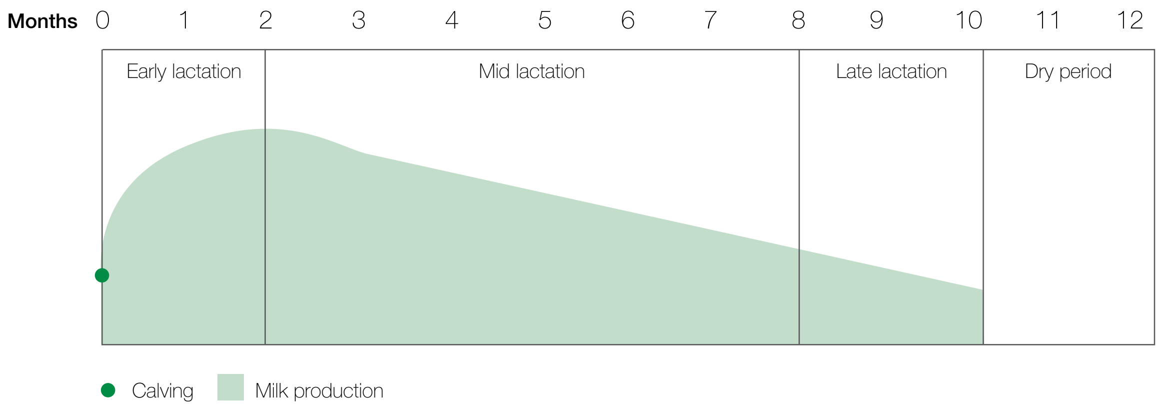


Source: Adapted from Elanco 2009.

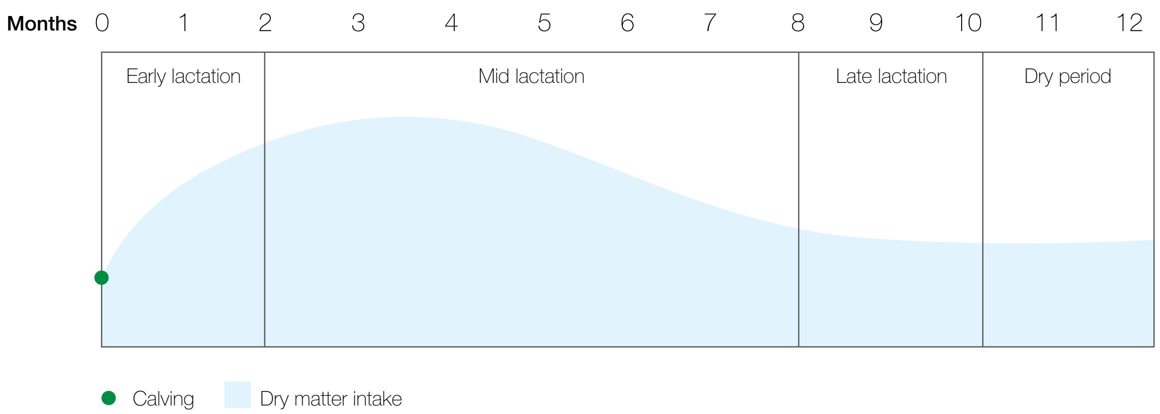
COW BODY CONDITION



MILK PRODUCTION



DRY MATTER INTAKE



Source: Adapted from Elanco 2009.

BODY CONDITION

A cow usually takes off body condition for up to about three months and uses this as an energy source to produce milk.

The dip in body condition occurs even if the cow is well fed and in good condition at calving.

The goal is to shorten the time the cow is losing condition, to optimise fertility and to have less condition to regain at the end of lactation.

This goal is achieved by feeding an energy-dense, protein-rich diet and managing the transition to maintain dry matter intake.

Body weight alone is not a good indicator of body reserves.

This is because the relationship is affected by factors such as the cow's number of calvings, stage of lactation, frame size, gestation and breed. In addition, because tissue mobilisation in early lactation occurs as feed intake increases, actual decreases in weight can be masked by gut-fill. It is for this reason that numerical body condition scoring systems started to appear in dairy research and on-farm in the 1970s.

10

MILK PRODUCTION

Cows need more energy and protein as milk production increases, and less energy and protein as production declines.

Taking off body condition allows the cow to produce more milk and to achieve higher peak production than would be possible from the diet alone.

To do this however, the cow must have the body condition available to lose. The cow must have put on body condition late in the previous lactation or during the early dry period.

DRY MATTER INTAKE

Remember that peak lactation does not coincide with peak intake, so most cows lose body condition in early lactation to make up for any shortages in energy intake.

Peak lactation can be important for how a cow will produce for the rest of the lactation.

Dry matter intake at the start of lactation can vary. Good transition management can increase the intake of dry matter.

FEED REQUIREMENTS: CALVING TO PEAK LACTATION

Feeding the herd well in early lactation to maximise the peak can be hard. Hormonal changes, mineral requirements, immune function and diet can all impact appetite.

At calving, appetite may be depressed by 25% or more. In the past, this was thought to be because the volume of the rumen is reduced by the growing calf. Current thinking is that hormonal influences have more to do with the drop in DM intake.

10

See page 10.9 Hepatic oxidation theory.

After calving, it takes time for the rumen to 'stretch'. It is not until about 10–12 weeks into lactation that a cow's appetite reaches its full potential, and this is only if it has free access to energy-dense feed.

Although level of intake is primarily determined by milk yield and stage of lactation, it can be manipulated.

The table opposite shows that cows are better able to eat enough to meet their energy needs if they are fed an energy-dense diet.

By providing a high-quality diet – one that is energy-dense and highly digestible – energy intake can be increased.

600 kg cows walking 5 km, fed diets of different energy density and producing at three levels of milk production: amounts of DM required daily

		Feed intake (kg DM/d)	
Milk yield (litres/day)	ME requirement (MJ/kg DM)	11 MJ/kg DM	12 MJ/kg DM
20	188	17.1	15.7
30	245	22.3	20.4
40	300	27.3	25

Source: Adapted from Grainger et al. 1982.

Milk yield at the peak of lactation sets up the potential milk production for the year. Remember, one extra litre per day at the peak can mean more than 200 litres for the full lactation.

> **When cows cannot eat enough to satisfy their energy requirements, they mobilise body tissue to help make up the shortfall.**

A cow producing 30 L would struggle to eat 22 kg DM of feed at 10 MJ/kg DM at any time during lactation, let alone early in lactation when intake is restricted.

10

Since their capacity to eat is reduced in early lactation, cows will produce a greater amount of milk from more energy-dense feed. This is because they have to eat less dry matter to receive an equivalent intake of energy.

If cows are underfed in early lactation, they partition less energy to milk and more to body condition over the whole lactation.

The underfeeding affects milk production for the whole lactation and also affects fertility. An example is given in the table below.

Effect of feeding level after calving on milk production, live weight gain and fertility in the first 20 weeks

Level of feeding		**Milk** (litres)	**Fat** (kg)	**Live weight gain** Wks 10–20 (kg/day)	**Days to first heat**	**Days to conception**
Weeks 0–5	Weeks 5–10					
High	**High**	2998	133	0.36	38	82
Low	**High**	2818	123	0.55	52	82
High	**Low**	2668	113	0.45	38	95
Low	**Low**	2138	90	0.62	52	95

Source: Grainger et al. 1982.

> **The depth to which cows drop into negative energy balance in early lactation and the subsequent drop in fertility has more to do with feed intake pre- and post-calving than milk production.**
>
> **For further information see Butler WR (2013) *Metabolic and reproductive interactions in dry and transition cows*. InCalf Reproduction Symposium May 2013, Melbourne. Dairy Australia.**

Calorimetric studies with high-yielding cows measured a mean negative energy balance of 22 MJ/day at week 6 of lactation, declining to 9 MJ/day by week 12.

Beever (2003) estimated these losses approximated to the mobilisation of 60 kg of body fat, assuming that fat will be the major tissue to be mobilised.

Even with lower-yielding cows fed a more modest diet and lower peak yields, milk production in week 1 was 33.8 L/day, of which 10.8 L/day (or 32%) was estimated to be derived from mobilised tissue.

However, these cows returned to positive energy balance more quickly than the high-yielding cows.

By week 30 of lactation, the higher-yielding cows had still only replaced 55% of the tissue they had used earlier.

For further information, see Beever DE (2003) Managing dairy cows for optimal performance. *Recent Advances in Animal Nutrition in Australia* 14, 33–47.

FEED REQUIREMENTS: MID LACTATION TO LATE LACTATION

Mid- to late-lactation milk yield declines while cows attempt to replenish their body condition stores ready for their next lactation.

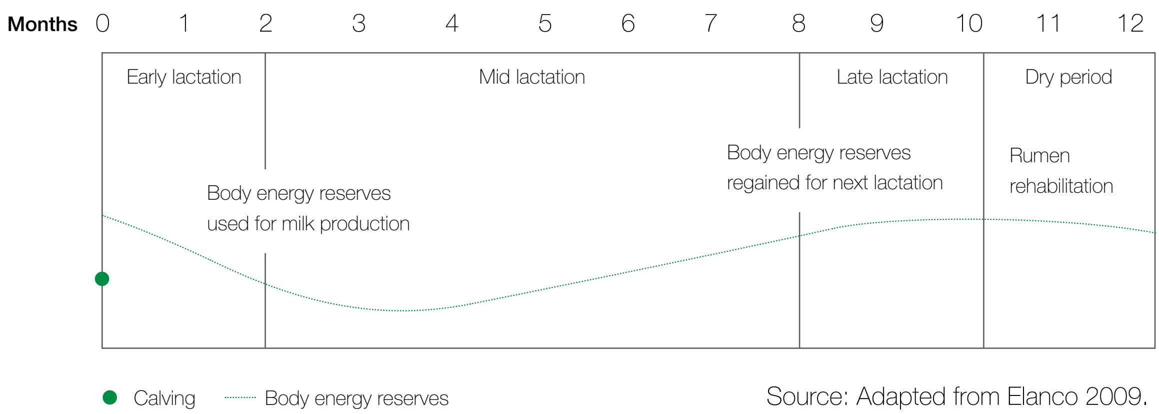
After peak lactation, with ad lib feeding (such as total mixed rations), a cow's appetite gradually increases until it can consume all the nutrients required from high-quality feed as there is no physical restriction on intake. During this time, the cow tends to maintain condition.

Although the energy required for milk production is less demanding during this period because milk production is declining, energy is still important. This is because of pregnancy and the need to regain body condition as an energy reserve for the next lactation. In fact, energy requirements in mid lactation and late lactation are not much less than those in early lactation (see Ch 12).

It is generally more profitable to improve body condition in late lactation rather than in the dry period.

Cows use energy more efficiently for condition gain while still lactating rather than when they are dry.

FLUCTUATING BODY ENERGY RESERVES



Source: Adapted from Elanco 2009.

HEPATIC OXIDATION THEORY OF FEED INTAKE CONTROL

The control of intake in ruminants is very complex, and it would be negligent to suggest intake is only controlled by gut distension. There are numerous metabolic and hormonal signals, many of which emanate from the diet, that are thought to be implicated. In a recent review, Allen et al. (2009) summarised the intricacies of what is termed the hepatic oxidation theory (HOT) of the control of feed intake.

This theory involves satiety signals from the liver to the brain that are generated by interactions between propionate and lactate from rumen metabolism, non-esterified fatty acids (NEFA) from tissue mobilisation and insulin, glucose and adenosine triphosphate (ATP).

The theory is well established for non-ruminants, but its application to ruminants presents some challenges for a number of reasons including:

- ruminal fermentation alters the type and pattern of metabolites (products of digestion) absorbed
- metabolites oxidised in the liver of ruminants differ from those in non-ruminants
- gut distension can moderate the metabolic effects.

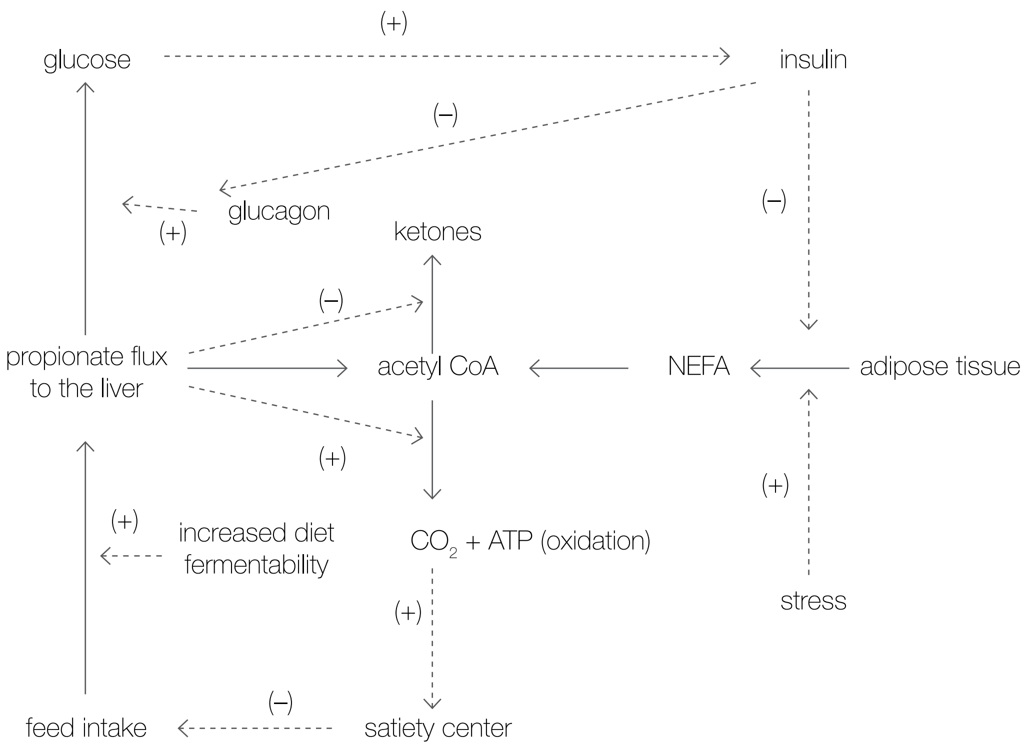
Hepatic oxidation theory – control of feed intake

Physiological state	Far-off	Close-up	Fresh	Peak-mid	Late maintenance
Insulin	High	Low	Low	Med	High
Insulin sensitivity	High	Low	Low	Med	High
Glucose demand	Low	Med	High	Med	Low
Energy partitioning	BC	BC	Milk	Milk	BC
Control of feed intake	GF	HO	HO	GF	HO

BC = body condition, GF = gut fill, HO = hepatic oxidation

Source: Allen MS 2009.

Allen (2009) presents a compelling case for the role of the hepatic oxidation theory, but suggests that the control of food intake by distension and hepatic oxidation are not mutually exclusive.



Solid lines show the flow of carbon

Dashed lines show stimulation/ inhibition of flow

Propionate uptake by the liver can be used for gluconeogenesis, utilising ATP, or oxidised in the tricarboxylic acid (TCA) cycle through acetyl CoA, producing ATC and stimulating satiety.

Acetyl CoA produced from ß-oxidation of fatty acids and other ketogenic fuels is oxidised in the TCA cycle or exported as ketones. Decreased insulin concentration, increased insulin resistance and stress increase lipoysis, thereby increasing the pool of acetyl CoA through of NEFA. Propionate uptake during meals stimulates oxidation of acetyl CoA to CO_2, rapidly generating ATC and stimulating satiety.

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11

FEEDING DAIRY COWS – BASIC PRINCIPLES

11

Dairy farm profit is linked to the efficient use of home-grown feeds and purchased supplements. Both affect carrying capacity, milk yield and milk composition.

Limitations in milk yield and composition can exist because of deficiencies of specific nutrients, the amount of pasture present or the amount of pasture on offer (the pasture allowance).

Remember, lactating cows consume more dry matter than dry cows.

Higher producing cows consume more than lower producing cows when grazing conditions allow.

DIGESTIBILITY

A cow's diet often comprises dry matter of different types, each with a unique blend of carbohydrates, proteins and fats. Some components can be digested and can provide the cow with an energy source, while other components cannot.

Feed tests often contain information relating to the digestibility of dry matter (DDM). These results represent the percentage of the feed dry matter actually digested by the animal. This percentage is estimated by using a laboratory method which is standardised against DDM values from feeding trials.

The quality of feed is often defined in terms of the degree to which it is digestible:

- high-quality feeds have a DDM value of over 65%
- feeds below 55% DDM are of poor quality.

Poor-quality feeds are feeds that are less digestible and if fed, the cow cannot extract the same level of energy as it could from feeds with a higher DDM value. Cows will not maintain bodyweight even if they have free access to this type of feed.

DDM – DIGESTIBILITY OF DRY MATTER

Digestibility refers to the portion of feed dry matter that can be digested by the cow: the portion that is not excreted in the faeces.

High quality feeds have a DDM value over 65%.

RATE OF DIGESTION

The rate of digestion depends on:

- **particle size**
- **feed quality**
- **feed composition.**

If nutrients are in short supply, microbial growth is retarded and so is the rate of digestion of the feed.

11

RATE OF DIGESTION

Rumen microbes find some components easy to break down, and these move through the cow's digestive system at a faster rate.

Rumen microbes specialise in terms of the components they can digest. The rate of digestion is affected by the number and types of microbes present in the rumen, which depends on the prevailing pH conditions and whether or not adequate nutrients are available to promote the growth and reproduction of the microbes. If cows lack sufficient energy from carbohydrates and protein, rumen fermentation will be limited and the growth and multiplication of microbial populations will be compromised.

The figure below shows the relationship between digestibility and rate of digestion of some common feeds.

Source: Adapted from Orskov 1987.

INTAKE AND APPETITE

Do cows with large appetites become high yielders, or do high-yielding cows eat more?

There is a relationship between dry matter intake and milk yield. Milk yields are generally a direct result of the amount of pasture and supplements consumed despite the fact that peak feed intake occurs some time after peak lactation (see Ch 10).

Cow size and feed quality are two major factors that influence feed intake.

A cow generally eats up to 4% of its body weight. It is rare under most practical conditions to get beyond this: total mixed rations is an exception. If 450, 500 and 550 kg cows eat the equivalent of 4% of their body weight, this equates to 18, 20 and 22 kg DM/day respectively.

Cows of the same body weight can differ in appetite, in rumen capacity and in grazing habits.

Intake increases as digestibility increases, and because the food moves more quickly through the digestive tract, this makes way for more food to be eaten.

High production needs high-quality supplements as well as high-quality, home-grown feed.

POTENTIAL & MAXIMUM INTAKE

The intake of cows grazing pasture is generally lower than in animals fed a total mixed ration (TMR) diet. This is because grazing cows spend longer away from feed when walking to and from milking.

Walking and grazing activity in pasture-based systems expends energy that is not required in TMR systems. Plus, time off grazing means fewer mouthfuls. The energy density of each bite is often different too, due to variations in pasture quality and allowance.

11

Dry cows can generally only eat a maximum of 2% of bodyweight, which reduces further as calving approaches.

The maximum potential herbage intake for a grazing cow is around 4.2% of bodyweight. In practice however, it is usually in the range of 3–4% of live weight.

!

ADVISER ALERT

Mertens (1994) developed the following equation which relates potential intake constraint to both cow size and the NDF of the diet.

(Live weight x (120 ÷ NDF%))/100 = kg DM/day max. intake

This equation is widely misunderstood. It is not the maximum NDF intake of cows, but the maximum NDF intake that can be digested and passed per day while also optimising milk production. NDF may require adjustment for particle size and feed digestibility because they affect rumen fill, NDF processing capacity and rumen flow rates.

While this formula was not designed for pasture-based systems and does not always accurately reflect intake in pasture-based systems, it is still valuable to provide an indication of the impact of high-fibre diets on potential intake.

The optimal NDF intake constraint in pasture-based feeding systems is probably higher than the 1.2% of bodyweight per day that maximises milk production. This is most likely due to the higher digestibility and lower effective fibre levels in high-quality pasture versus conserved forages, and the resultant faster rumen flow rates.

Source: Mertens DR 1994. Regulation of forage intake. In: Forage Quality, Evaluation and Utilization, (Ed. Fahey Jr. GG, Collins M, Mertens DR, Moser LE) American Society of Agronomy, Crop Science Society of America, Soil Science Society of America Madison: WI, USA. pp. 450–493.

FOR FURTHER INFORMATION:

Kolver ES, Muller LD (1998) Performance and nutrient intake of high producing Holstein cows consuming pasture or a total mixed ration. *Journal of Dairy Science* **81**, 1403–1411.

INTAKE: ENERGY DENSITY (PASTURE VERSUS TOTAL MIXED RATION)

Kolver and Muller (1998) studied why cows grazing without restriction on good-quality pasture produced less milk than cows fed with a well-balanced total mixed ration (TMR). They found that:

- cows fed a total mixed ration produced 44.1 kg milk/cow.day
- cows grazing pasture produced 29.6 kg milk
- both groups had unrestricted access to feed
- the difference in milk production was 15.4 kg.

This difference could be explained by several variables:

- grazing cows had an intake of 19 kg DM/cow.day; TMR cows had an intake of 23.4 kg DM/cow.day
- if the grazing cows had the same intake as the cows fed the total mixed ration an extra 9.4 kg of milk could have been produced
- the energy used for grazing and walking cost an estimated 3.7 kg of milk/day
- the energy cost to the cow of converting surplus protein in pasture to urea was 1.8 kg of milk/day
- differences in milk composition and live weight accounted for the rest of the difference in milk production.

This shows that if grazing dairy cows could simply eat more high-quality pasture, more than half of the difference in milk yield could be eliminated.

INTAKE: VFA SURGE AFTER GRAZING

The slug-feeding nature of two intense bursts of grazing produces surges of VFAs and impacts total willingness to consume dry matter over a 24-hour total.

FEEDING COWS SUPPLEMENTS

The primary aim of feeding a supplement in a pasture-based feeding system is to increase total metabolisable energy intake.

Supplements are generally classified by their ability to increase the nutrient density of the diet – in particular, the energy and protein density of the diet.

The milk response depends on the type of supplement used.

11

Responses to supplements need to be analysed in terms of the short-term and long-term milk response.

Consider a range of factors before making the decision to use a supplement.

- What is the limiting nutrient in the current diet?
  It may be energy, protein, fibre or a combination of all three, due to low pasture intake.
- What supplements are available?
  Does what is available match what is required?
- What is the nutritive composition of the supplement?
  A feed test analysis is the only way to know for sure.
- What are the relative costs?
  Compare supplements on the basis of cents/MJ ME and $/kg crude protein.
  Costs should be per unit of feed consumed and include storage, wastage, labour and depreciation of feed-out equipment.
- What are the practical implications?
  Consider facilities for storage and feeding, machinery for feeding out, labour requirements and reliability of supply.
- What are the nutritional implications?
  Think through the effect of the supplement on diet balance, the likelihood of acidosis or other potential problems.

PASTURE SUBSTITUTION

Ideally, feeding a supplement should increase the DM or ME intake by an amount equal to that of the supplement fed. However, grazing dairy cows generally reduce their pasture intake when supplements are fed.

'Substitution' refers to the reduction of pasture intake that occurs for each kilo of supplement consumed.

Substitution of a concentrate or forage supplement for pasture is generally between 0 and 1.0 kg DM pasture/kg DM supplement in healthy cows.

The major factor influencing the level of substitution is the amount of pasture consumed.

Substitution is generally greater when roughage (hay, silage) supplements are fed than when concentrates are fed. This is because roughages have greater volume and are digested relatively slowly.

If supplements are fed when pasture has not been well utilised, it is likely that there will be little or no increase in milk yield, and even more pasture will be wasted.

On farm, it is difficult to determine the precise amount of substitution that occurs.

Ensure residual pasture height (between clumps) is around 4–6 cm after grazing. If it is greater than this, it may impact subsequent pasture quality. Lower residuals can slow regrowth of the sward.

If stocking rates are high, or when pasture growth is slow, cows may be underfed on pasture. In these circumstances, post-grazing pasture mass will be less than ideal, so some level of substitution could be beneficial by reducing the pressure on the pasture and allowing faster regrowth.

Adjusting supplement feeding to enable a 4–6 cm pasture residual is a key management tool for driving profitability of pasture-based systems.

!

Substitution may be caused by negative associative effects in the rumen. Interactions between the digestion of concentrates and pasture may reduce the rate of fibre digestion and consequently pasture DM intake.

Other factors, such as the cow's preference for feeds and the physiological constraints of grazing, also contribute to substitution in grazing cows.

A major effect of supplements on the level of substitution may also be through reductions in grazing time.

Constraints to grazing time that affect pasture intake, and therefore substitution, are pasture allowance, pasture mass and the physical structure of the plants that make up the sward.

11

RESEARCH ON SUBSTITUTION

Results from a short-term grazing experiment conducted at the Ellinbank Dairy Research Centre in Gippsland provide an example of what substitution might mean on a dairy farm.

Six herds in early lactation rotationally grazed spring pastures. Three pasture allowances were used: low, medium and high. At each pasture allowance, the daily diet of one herd was supplemented with 3.2 kg DM/cow of commercial pellets while the other herd was not fed pellets at all.

At the high pasture allowance, the unsupplemented cows utilised less than 50% of the pasture on offer. The total DM intake of the supplemented cows on the high pasture allowance increased by only 1.0 kg/day, and milk yield by 0.9 L/day. They consumed 0.7 kg less pasture for every kg of supplement fed: that is, the level of substitution was 0.7. The milk production response was 0.3 L/kg of supplement fed.

At the medium and high pasture allowances, milk responses increased to 0.7 L and 1.0 L/kg DM respectively, while substitution declined to 0.35 and 0 kg DM reduction in pasture intake/kg DM of concentrates consumed.

The effect of pasture allowance and concentrate feeding on pasture intake and milk yield in early lactation

	Pasture allowance					
	33 kg/cow		17 kg/cow		8 kg/cow	
Supplement (kg DM/cow.day)	0	3.2	0	3.2	0	3.2
Pasture allowance (kg DM/cow.day)	33	33	17	17	8	8
Pasture intake (kg DM/cow.day)	15.9	13.7	11.8	11.0	6.0	6.3
Total intake (kg DM/cow.day)	15.9	16.9	11.8	14.2	6.0	9.5
Substitution (kg DM reduction in pasture intake/kg DM of supplement fed)	-	0.69	-	0.25	-	0
Milk yield (L/cow.day)	23.1	24.0	20.9	23.1	15.4	18.5
Milk response to supplement (L milk/kg DM supplement fed)	-	0.28	-	0.69	-	0.97

Source: Grainger and Mathews 1989.

If cows are hungry (such as if they have a low pasture allowance) they will eat the additional supplement offered with little reduction in pasture consumed. If cows are not hungry (as with a high pasture allowance) they will eat the supplement offered and reduce the amount of pasture eaten. This is more like a swap of what is eaten rather than increasing total intake.

For further information on milk response to concentrates, see Ch 14.

Energy corrected milk
Standardised litre of milk: that is, same fat, protein

ADVISORY ALERT – REALISTIC EXPECTATIONS FOR SUPPLEMENTATION

Theoretically, a kg of concentrates with 12.5 MJ of ME, for example, has enough energy for 2.5 L of milk at 5.0 MJ/L. However, it is unrealistic to assume all of the extra estimated ME supplied by an increase in the amount of supplement fed can be partitioned to milk.

Allowances must be made for all the inefficiencies associated with digestion and metabolism, those associated with deposition/mobilisation of body tissue and any substitution that might occur.

It is only feasible to produce 2.0 kg of energy-corrected milk or more from 1 kg DM of grain or concentrates if:

- all of the additional ME is partitioned to milk production, with none diverted to maintenance, body tissue gain or reproduction
- there is no substitution of the supplement for grazed pasture or conserved forage
- there are no negative associative effects between the supplement and grazed pasture or conserved forage
- there is no reduction in the ME of the feed because of the level of feeding
- there are no other nutrient limitations (such as NDF, metabolisable protein, specific amino acids, minerals or vitamins).

The only scenario in which a marginal milk production response to a kg DM of extra supplement of 2.0 kg of energy-corrected milk or more could possibly occur is where cows are grossly underfed and producing significant quantities of milk from tissue mobilisation.

PROCESSING SUPPLEMENTS

Processing supplementary feeds by crushing, grinding or chemical means enhances the ability of the rumen microbes to digest the contents of the grains.

Feeding whole, unprocessed cereal and oilseed grains generally leads to low utilisation of the supplement and low milk responses.

PROCESSING GRAINS

11

The seed coat of grains must be cracked or broken in some manner to enable the rumen microbes to digest the grain contents. Oats are an exception to this rule. Trials have found little difference in milk response to whole or processed oats.

The most common forms of on-farm processing currently used in Australia are dry rolling, disc and hammer milling.

Other forms of processing are also carried out on a larger scale by stock feed manufacturers and include chemical processing, steam pelleting and steam flaking.

Rolling, disc and hammer milling

Generally, sorghum and maize require fine grinding (hammer-milling) to maximise digestion, while rolling and cracking are preferable for wheat, barley and triticale. Ideally, the grains should be broken into three or four pieces. Reducing particle size makes the grain starch more readily accessible in the rumen. In theory, this finer grain improves ruminal and total tract utilisation but it results in digestive problems if high levels of grain are fed.

Fine grinding of grain can reduce its palatability to cattle. Where grains are not over-processed, some starch can escape to the small intestine for digestion. This can be beneficial because of the provision of glucose directly to the cow.

Chemical processing

Treating grains with an alkali (such as sodium hydroxide) is also an option. Such treatment weakens the fibrous seed coat, allowing rumen bacteria to enter, and results in increased digestibility. Alkali-treated grain is digested more slowly than mechanically processed grain, so there is less chance of acidosis occurring. Note that using an alkali (such as sodium hydroxide) may lead to problems in handling the grain, with treated grain tending to solidify.

Other chemical methods (such as using ammonia to treat grain) can reduce these handling problems while providing the same benefits as the alkali treatment.

Steam pelleting

At high levels of feeding, pellets may have an advantage over straight cereal grains. This is because hammer milling the grain increases its surface area and therefore access to the starch by the microbes. In terms of rumen fermentation, the heating also partly gelatinises the starch, increasing breakdown.

The heat treatment used in the production of pellets may increase the protection of starch and protein from rumen degradation and stimulate greater pasture intake.

PROCESSING PROTEIN FEEDS

As with cereal grains, processing feeds high in protein can lead to their more efficient use.

Mechanical treatment of legumes or oil-type grains increases their digestibility. For example, rolled or hammer-milled lupin grain can increase production and give an 18% improvement in digestibility.

Heat or chemical treatment (such as with formaldehyde) of feeds high in protein can reduce their degradability in the rumen (and increase the bypass effect).

Note that excessive heat or formaldehyde may also reduce the digestibility of the UDP in the small intestine.

Screw pressing of oil-type grains yields a greater proportion of UDP in the meal. This occurs because the heat produced by pressing increases the protection of protein from rumen degradation.

INDICATORS OF AN UNBALANCED DIET

There are a number of indicators of unbalanced diets that are readily observable. These include:

- milk yield and composition (low milk fat and protein tests)
- cow signs like rumination, rumen fill, manure evaluation, body condition, posture and locomotion

Whilst not a precise science, these signs may give the nutritionist or farm manager a hint of what is happening to, and within, the animal.

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For further information on SARA, see Ch 19.

Low fat test

A drop in fat test may occur when cows consume a low-fibre diet – a diet high in cereal grain and lush pasture, for example – and /or suffer subacute ruminal acisosis (SARA). Fibre is fermented by the rumen microbes and produces the end product acetate. Acetate is used to produce milk fat. If fibre is low, acetate production will decline relative to propionate production. This results in a drop in milk fat production.

The easiest way to increase the fibre content of the diet is to feed hay. However, feeding poor-quality hay may also result in a drop in dietary energy intake, causing milk and protein yield to fall. Moreover, simply feeding a bit of hay may not have the desired effect if the cows just substitute hay for pasture, thereby not increasing their fibre intake significantly.

Another reason for a low fat test can be excess PUFAs in a cow's diet. For further information, see page 8.8 Milk fat depression: New thinking on the causes.

Low protein test

It is important that glucose is metabolised from sources other than amino acids because protein is an inefficient source of energy.

Low milk protein content is common in early lactation when the cow is in negative energy balance. A shortage of energy reduces protein utilisation by rumen microbes. A shortage of energy results in the supply of microbial protein being reduced: microbial protein is the cow's major protein source.

Under most circumstances, providing a higher energy diet will lift a protein test, although any increase is likely to be small.

As well as cow signals, sometimes the pasture can also reveal dietary issues with grazing animals. For instance, urine scalds in the paddock or the smell of ammonia in the dairy are indicative of high protein levels in the pasture or a high protein-to-carbohydrate ratio.

In these cases, dietary protein is being wasted and is excreted in the urine.

RUMINATION

After an initial grazing period, cows normally start to ruminate or chew their cud for around 35–40% of the day. Chewing for about 27–36 minutes per kg of dry matter is normal. If rumination is not occurring in a large percentage of the herd, there may be a lack of fibre in the diet. Look for changes in milk composition, specifically reduced milk fat concentration.

Remember...

Not enough long or 'effective' fibre

= not enough chewing

= not enough saliva

= drop in ruminal pH

= increased risk of acidosis

For further information on the role of fibre and acidosis risk, search for *Dairy Australia: Effective feeding quick checks.*

RUMEN FILL

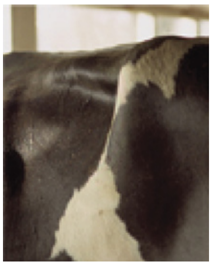
A five-point scoring system has been developed to assess rumen fill and is used in feed-lot systems.

Rumen fill tells the observer something about how well the cow is eating today, and whether enough is being consumed.

Unfortunately, because of very rapid transit times, cows grazing very good quality pasture would probably be scored near the bottom of the range at all times, unless they were suffering from bloat.

Assessing rumen fill

Looking at the cow from behind, the left side (just forward of the hip bone and immediately below the short ribs) ranges from sunken to filled-out.



1.

SCORE 1

Deep-shrunken left side; the skin on top of the diagonal protuberance of the lumbar vertebra is caved-in. The fold of skin goes clearly vertically down from the hip bone. The rumen pit behind the rib bow is more than a hand's width. Seen from the side, there is a rectangular flank view.

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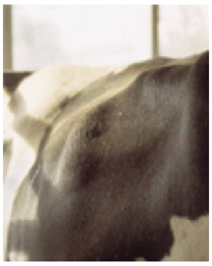
2.

SCORE 2

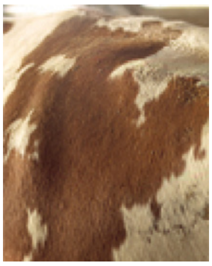
The skin over the diagonal protuberance of the lumbar vertebra is caved-in. The fold of skin from the hip bone slopes to the front, to the rib bow. The rumen pit behind the rib bow equals a hand's width. Seen from the side, there is a triangular flank view.



3.

SCORE 3

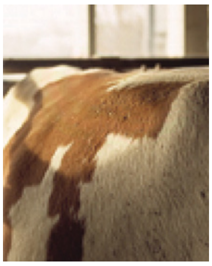
The skin over the diagonal protuberance of the lumbar vertebra first goes vertically down and then curves to the outside. The fold of skin from the hip bone is not visible but the rumen pit behind the rib bow can be seen.



4.

SCORE 4

The skin across the diagonal protuberance of the lumbar vertebra is curved directly to the outside. Behind the rib bow, no rumen pit can be seen.



5.

SCORE 5

The diagonal protuberance of the lumbar vertebra is not visible because of a well-filled rumen. The belly skin is strongly stretched. No transition from the side of the ribs can be seen.

Source: Zaaijer D, Kremer WDJ and Noordhuizen JPTM (2001) Dairy cow monitoring in relation to fertility performance. Pharmacia Animal Health.

MANURE CONSISTENCY

Evaluating manure can provide information about general health, rumen fermentation and digestive function. The consistency of the faeces largely depends on its water content and is a function of feed moisture content and the amount of time feed remains in the animal.

Cows fed total mixed rations have manure with a medium porridge-like consistency which forms a dome-shaped pile 3–5 cm high.

Very fibrous diets result in coarse, dry, high cow pats.

Manure that is very loose and watery is often seen in cows grazing high-quality pasture and is indicative of the high water and protein content of the diet and its low fibre.

Manure can appear foamy or bubbly. This may indicate lactic acidosis or excessive caecum fermentation.

The presence of large forage particles or undigested grain may also indicate that cows are not ruminating adequately or that passage rate is accelerated, due to an inadequate intake of effective fibre.

Observation of a substantial amount of undigested grain particles may indicate grain engorgement or improper grain processing.

Large proportions of undigested grain or long forage particles in the manure may be an indication of poor rumen fermentation.

!

MANURE EVALUATION IS NOT A PRECISE SCIENCE

Manure scoring was developed in intensive feeding systems and tells us something about the quality of yesterday's feed and whether the rumen is healthy and functioning properly. It cannot provide definitive answers to nutritional questions but it may give the nutritionist or farm manager a hint of what might be happening during the digestive process.

Note that a diet including good-quality pasture will probably put a cow towards the bottom of the scoring system. However, severely loose manure may indicate diarrhoea, high parasite burdens, high endophyte levels or nitrate poisoning rather than simply wet, lush, low-fibre pasture.

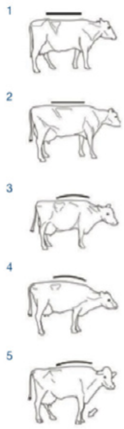
Scoring manure

Score at least 25 fresh manure pats in the paddock using the scoring system outlined below. If more than five of the 25 pats are scored at 1 or 2, take action.

Scoring manure

	Consistency	Visual
SCORE 1	Very liquid manure. May 'arc' from the cows rump. The bubbles indicate an unstable rumen, fast gut flow and hindgut fermentation. Seek nutritional or veterinary advice urgently.	
SCORE 2	Runny manure which will splatter on impact and may form loose piles less than 25 mm high. Increase effective fibre content of the diet. Check that all cows have equal access to feed. Contact an adviser if the manure score does not improve within a couple of days.	
SCORE 3	Manure forms a soft pile 40–50 mm high, which may have several concentric rings and a small depression in the middle. It will stick to the toe of a shoe. The manure indicates adequate fibre in the diet.	

Source: 'Effective feeding quick checks Fact Sheet' 2013 Dairy Australia Fact Sheet: Quick manure checks. Original photos: Ian Lean.



Dairy Knowledge; Efficient Cow Comfort; DeLaval Cow Comfort Line document, p. 10 Locomotion score

Locomotion Scoring Brochure and DVD

For more information about locomotion scoring dairy cattle, request your free copy of the *First Step Locomotion Scoring of Dairy Cattle* brochure or DVD.

Request A Free Copy

http://www.zinpro.com/lameness/dairy/locomotion-scoring

LAMENESS

Lameness in a herd has several causes. While it may be due to leg and hoof injuries from poor maintenance of tracks and yards, and other physical factors, lameness may also be due to laminitis, as a consequence of ruminal acidosis.

Lameness can cause pain for a cow and impair her ability to graze and compete for food. If many cows are lame, it can have significant impacts on herd production and reproductive performance, and increase treatment costs and the risk of culling.

Early detection is therefore critical.

Locomotion scoring was first outlined by Sprecher et al (1997) and is based on the observation of cows' standing and walking gait, with special emphasis on back posture.

SCORE 1

Normal. Stands and walks normally. All feet placed with purpose.

SCORE 2

Mildly lame. Stands with a flat back but arches when walks. Gait is slightly abnormal.

SCORE 3

Moderately lame. Stands and walks with an arched back. Short stride with one or more legs.

SCORE 4

Lame. Arched back standing and walking. One or more limbs favoured, but at least partially weight-bearing.

SCORE 5

Severely lame. Arched back, refuses to bear weight on one limb. May refuse or have great difficulty moving from a lying position.

The Reference Advisory Group on Fermentative Acidosis of Ruminants provided the following rules of thumb.

- More than 5% prevalence of lameness score 2 cows is cause to investigate acidosis as a possible factor in a lameness problem.
- Track condition, moisture and other disorders must also be assessed.

For practical management information search for 'Dairy Australia: Healthy hoof lameness field guide'.

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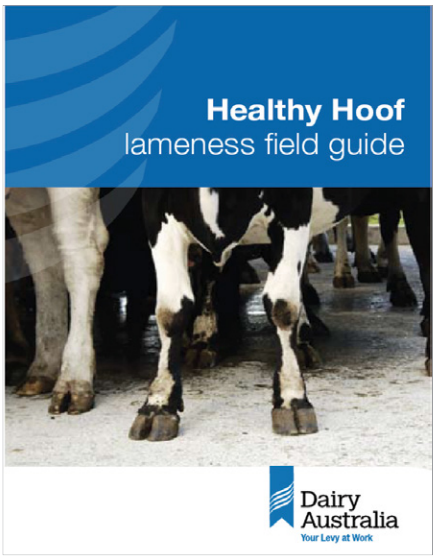

Top: lamintic rings. These are the result of an outbreak of acute laminitis approximately two months previously.

Above: paint brush sole haemorrhages and white line disease.

The scoring cards photos developed by Zaaijer, Kremer and Noordhuizen are no longer available. The images have been widely reproduced in various commercial publications including Cows Signals by Jan Hulsen, the DeLaval Milk Production information site http://www.milkproduction.com/Library/Scientific-articles/Housing/Cow-comfort-12/ and The CRV Dairy management guide which is online at http://issuu.com/crv4all/docs/dmg_feeding.

For further information on rumen fill scoring see the technical note listed below.

Journal of Dairy Science Volume 93, Issue 8, pp. 3635–3640, August 2010: Technical note: Evaluation of a scoring system for rumen till in dairy cows.

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12

FEEDING COWS PASTURE

When attempting to optimise milk production from pasture, it is important to understand that it is a matter of balance. The aim is to achieve the right balance of pasture growth, nutritive characteristics, persistence of sown species and feed utilisation.

Complex plant, animal and climatic factors interact to influence pasture consumption.

Pasture intake estimates are crucial to assessing feed conversion efficiency and for formulating balanced diets for dairy cows.

Animals generally try to consume feed to realise their genetically determined capacity for growth and/or milk production.

While pasture intake by dairy cows increases linearly with body weight, intake is also affected by body condition, milk yield and lactation stage. Disease and climatic stresses can also affect feed intake.

GRAZING BEHAVIOUR AFFECTS PASTURE INTAKE

A cow's day can be divided into three activities: grazing, ruminating and resting.

The timing of a cow's grazing during a 24-hour period depends to a large degree on the management of pasture allocation. The pattern is affected by regular activities such as milking or movement of stock onto different pastures.

The average time spent grazing is about 8.5 hours. Around 7–8 hours are spent ruminating. Grazing time rarely exceeds 10 hours per day. Short periods of night grazing are not uncommon and are most likely to be the main period of grazing on very hot days (above 30°C).

While most grazing occurs during daylight, cows don't eat continuously but tend to graze for blocks of time. On the right pasture, a cow can consume a major proportion of daily intake in two 3-hour grazing periods.

Bite size is the most critical determinant of pasture intake.

FACTORS AFFECTING GRAZING BEHAVIOUR

Pasture DMI	=	**Grazing time (min/d)**	x	**Biting rate (bites/min)**	x	**Bite mass (g DM/bite)**
Pasture dry matter intake		Grazing time minutes per day		Biting rate bites per minute		Bite mass grams dry matter per bite
				↑		↑
				Animal factors • milk production • genetic merit • size		**Pasture factors** • height • density

Source: Bargo 2003.

Bite size is reduced when pasture mass is low. Cows compensate by increasing both grazing time and rate of biting but this does not fully compensate for the decrease in intake per bite.

Rate of biting is normally around 36,000 bites per day:

Bite fracture force influences pasture intake: the greater the force that is required to fracture the herbage, the lower the intake.

As grasses grow, they develop different amounts of structural carbohydrate. The stemmy material and toughness of this carbohydrate increases as the grass matures.

Mature stem is harder to harvest than young stem.

Stem is harder to harvest than leaf.

If a cow puts equal effort into harvesting pasture, more leafy pasture can be eaten than stemmy pasture.

Published or book values for nutritive characteristics for pastures are based on a 'cut-to-ground-level' method and samples are randomly selected.

Cutting pastures to ground level is undertaken in research to ensure that samples are harvested in a consistent manner. While the values for nutritive characteristics are often comparable, they do not always reflect what the cow has actually consumed as a result of selective grazing.

On average, it is estimated that cows select 5–15% more metabolisable energy than is estimated to be on offer, 25–40% more crude protein and 5–25% less neutral detergent fibre.

Selective grazing affects intake

Cows are selective about what they eat of the pasture on offer and prefer the leaf fraction of pasture plants.

As a general principle, cows eat more of what they like and less of what they don't like.

Cow don't like soiled pasture as found in night and sacrifice paddocks. They also do not like mature pastures with stemmy and dead plant matter, or weeds. When given the opportunity, cows select green herbage in preference to dead matter. Cows have a preference for clover and young, succulent grass.

The nutritive characteristics of a pasture sward vary with the stage of maturity of the dominant pasture species. For example, clover-dominant pastures generally have higher crude protein levels than do perennial ryegrass pastures. As cows prefer clover, they may select it out of the sward and as a result consume higher-than-expected levels of protein.

The nutritional value of pastures also varies with the season. When the dominant species begins to mature, the quality or nutritional value declines. This applies particularly to ryegrass. White clover, for example, grows well in the warmer conditions of spring/summer and its nutritive value declines less. Again, selective grazing by cows will make estimating the feed value difficult.

The degree of selection and how it changes the consumed feed value depends on grazing pressure – the stocking rate and pasture allowance – and the pasture mass.

Cows cannot be as selective when stocking rates are high or pasture mass is low.

Where high utilisation is achieved under strip grazing or small paddock rotational grazing conditions, the ability of cows to select within the sward is particularly restricted.

Selective grazing by cows makes it difficult to estimate the feed value actually consumed.

Where grazed pasture forms part of the diet, effective use of supplementary feeds depends on knowledge of the amount and nutrient content of the pasture actually consumed by the cows.

Definition: Selection factor

The difference between the quality of pasture cut to ground level and what the cows choose to eat.

Selective grazing affects estimations of intake – energy & protein

The differences in metabolisable energy (ME) between the leaves and stems of pasture plants are small.

Cows grazing perennial ryegrass/white clover pastures in spring or autumn consume material that is 5–15% greater in ME than pre-grazed pasture harvested to ground level. This is true across a wide range of pasture allowances.

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For lower quality pastures containing paspalum and summer-growing weeds, this differential is 0–5%.

The concentrations of crude protein differ markedly between leaf and stem in white clover, perennial ryegrass and paspalum.

Leaves have the most protein and are predominant in the upper levels of the canopy grazed by cows.

Concentrations of crude protein in consumed pasture are 25–40% higher than in pre-grazed pasture harvested to ground level. This is true for both irrigated and rain-fed pastures.

Crude protein concentrations in consumed pasture are seldom below 17% for pastures that are green, and can approach or exceed 30%, thereby generally exceeding requirements of cows at all stages of lactation.

!

ADVISER ALERT: THE SELECTION DIFFERENTIAL FOR PROTEIN HAS CLEAR IMPLICATIONS FOR THE CHOICE OF SUPPLEMENT

If ignored, potential losses in milk production are likely to occur because of the energy cost associated with excreting excess nitrogen.

This is particularly the case if considerable nitrogen fertiliser is used as is often the case in southern Victoria. It is also the case in spring in northern Victoria when pasture is plentiful and clover is most likely to dominate pasture swards.

Selective grazing affects estimations of intake – fibre

Neutral detergent fibre (NDF) concentrations in pastures are inversely related to digestibility. NDF concentrations are highest in summer and lowest during winter and spring. The concentrations of NDF in pasture on offer usually exceed those recommended for lactating cows.

Note that selective grazing may create a problem, particularly when cows graze pasture with a high clover content. Leaves have less NDF than stems and cows have a preference for both clover and leaves. This means that the NDF consumed from such pasture is lower (by 5–25%) than in the estimations of pasture on offer.

!

ADVISER ALERT: PRACTICAL IMPLICATIONS OF SELECTIVE GRAZING AND SELECTIVE DIFFERENTIAL

If a selection factor isn't applied to calculations you will underestimate what cows can eat. You also run the risk of low-fibre, particularly in early- to mid-spring diets. This can lead to sub-acute ruminal acidosis (SARA) and less efficient digestion of fibre, overloading the diet with protein and losing milk production.

Don't forget to apply your selection factor to your calculation.

SWARD FACTORS AFFECT PASTURE INTAKE

Pasture intake is affected by the following sward factors:

- pasture allowance
- pre-grazing pasture mass
- digestibility and palatability characteristics
- species composition of sward
- management of grazing.

Intake per bite is influenced by the amount of available pasture: the allowance and mass of pasture. Both variables can be controlled to some extent by management.

!

GENERAL PRINCIPLE: FOR A GOOD DAILY INTAKE OF PASTURE, OFFER COWS A BIT MORE THAN THEY CAN EAT IN A DAY

Offering a generous amount of pasture will allow the cow to select a higher quality diet. This increases both the rate of digestion and intake.

Remember though that there must be a compromise between the needs of the cow and the needs of the pasture. Aim to have a post-grazing pasture residual of 4–6 cm to maintain pasture quality at the next grazing and to achieve good re-growth rates.

Avoid offering cows so much pasture that waste occurs. This causes pasture quality to decline over successive grazings.

Definition: daily pasture allowance

The weight of pasture allocated per unit of animal body weight per day in a rotational grazing system involving individual grazing periods of no more than 1 or 2 days. Expressed as kg DM/cow/day

Allowance affects intake

The figure below shows that strong positive relationships have been found between intake and allowance. As the figure shows, increasing pre-grazing pasture mass results in an increase in pasture intake at common allowances.

Note that this relationship is also influenced by species composition.

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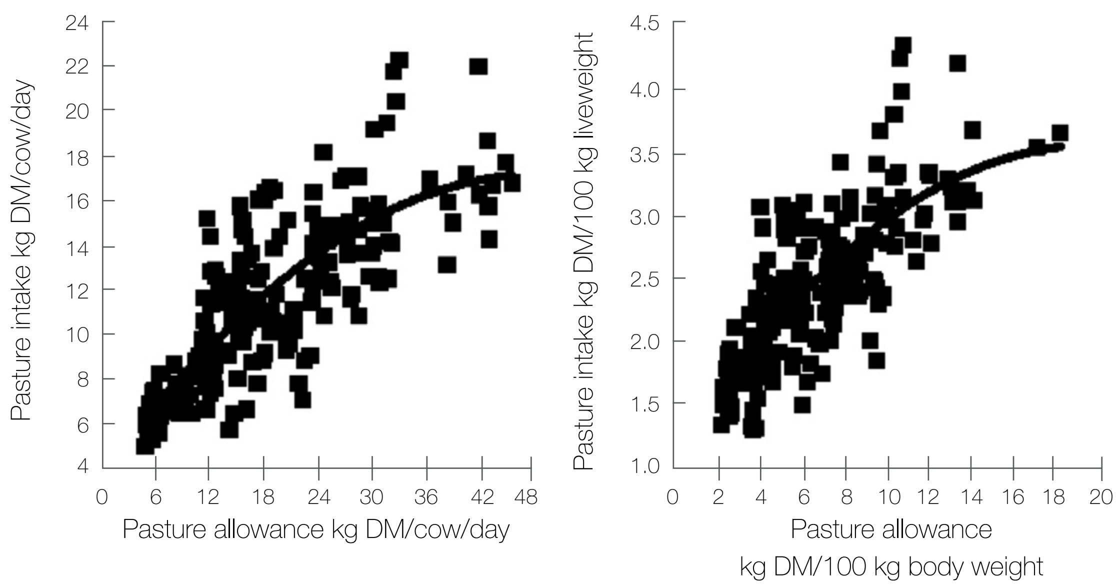
RELATIONSHIPS BETWEEN PASTURE INTAKE AND PASTURE ALLOWANCE BASED ON KG DM/COW/DAY OR KG DM/100 KG OF BODY WEIGHT



These relationships include variations in season and therefore pasture species, height or mass of pasture on offer and pasture quality.

Source: Stockdale 2000.

Definition: pasture mass

The total amount of pasture per unit of ground, usually above ground level. Expressed as kg or t DM/ha.

Mass affects intake

Longer pasture is easier to graze as it is easier to get a mouthful compared with the shorter pasture. This is true even if the total quantity of pasture is the same.

For example, intake per bite will be greater from a 10 cm tall pasture spread over 1 ha than from a 1 cm tall pasture spread over 10 ha.

Pasture mass has in the past been used interchangeably with other terms such as pasture present, pasture on offer, pasture cover and in some cases pasture availability. This last term implies all above-ground herbage can be eaten, which is not the case for grazing cows, so in general it should be avoided unless it is precisely specified.

Pasture yield should not be used interchangeably with pasture mass.

Digestibility affects intake

Digestibility refers to the portion of feed dry matter that can be digested by the cow: that is, the portion that is not excreted in the faeces.

Poor-quality feeds are feeds that are less digestible to the cow.

A cow's diet often comprises dry matter of different types, each with a unique blend of carbohydrates, proteins and fats.

Some components are able to be digested and can provide the cow with an energy source while other components cannot.

Feed analysis reports often contain information relating to the digestibility of dry matter (DMD), such as shown below. These results represent the percentage of the feed dry matter actually digested by the animal. This percentage is estimated by using a laboratory method which is standardised against DDM values from feeding trials.

Results of Analysis:

Test	Method	Units	01-A
Moisture	Wet	%	12.5
Dry Matter	Wet	%	87.5
Crude Protein (N x 6.25)	NIR	% of dry matter	14.5
Neutral Detergent Fibre	NIR	% of dry matter	46.1
Digestibility (DMD)	NIR	% of dry matter	65.3
Digestibility (DOMD)	Calculated	% of dry matter	62.1
Metabolisable Energy	Calculated	MJ/kg DM	9.6

12

The quality of feed is often defined in terms of digestibility.

High-quality pasture is leafy and contains little stem. It has the characteristics that allow the rumen microbes to easily break it down. On the other hand, mature plant material has a higher fibre content which is either not digested or slowly digested by the microbes.

High-quality feeds have a DDM value of over 65%. Feeds below 55% DDM are of poor quality.

If poor-quality feed is fed, the cow cannot extract the same level of energy as it could from feeds with a higher DDM value. Cows will not maintain their liveweight even if they have free access to this type of feed.

DIGESTIBILITY & NUTRITIVE VALUE: CLOVER AND GRASS MATURITY

As grasses flower and mature, their quality declines as soluble carbohydrates translocate from stem and leaves to flowers. This increases lignin in cell walls and decreases the ratio of leaf to stem.

The nutritive value of annual clovers does decline from flowering through to death, but not at the same pace as in grasses. Flowering in perennial clovers is not usually associated with large changes in nutritive value, despite leaf loss.

Although the differences in the energy levels of pasture species may seem small, consider this:

a **1 MJ increase** in energy density (MJ/kg DM) for an average intake of 15 kg DM/day is enough energy to produce an extra **2.5–3.0 L of milk/day**.

Nutritive characteristics of the sward

The nutritive characteristics of a pasture sward vary with the dominant species, the season, stage of maturity and height of the pasture species.

Clover-dominant pastures generally have higher crude protein levels than do perennial ryegrass pastures.

White clover grows well in the warmer conditions of spring/summer.

When the dominant species begin to mature, and this applies particularly to grasses, the quality or nutritional value declines.

In irrigated pastures, paspalum tends to dominate and depress the overall nutritive value.

Except in spring, when paspalum is still quite leafy, pastures dominant in paspalum tend to have less energy and protein than ryegrass/white clover pastures.

Pasture composition affects intake

Cows consume more in clover-dominant pastures than in grass-dominant pastures at equivalent allowances and masses.

Cows are more productive on clover than on grass so the composition of a sward has a major impact on animal production.

The key reason for the superiority of clover over grass is that:

- cows consume up to 30% more clover
- clovers contain less fibre than grasses of similar digestibility and, as a consequence, the intake of clovers is greater than that of grasses
- the intake difference is associated with the shorter time that clovers are retained in the rumen, due to particle shape
- cows will graze clover harder than grass, especially when pasture allowances are low.

Grazing basics

Graze pasture to approximately 4–6 cm height so it can grow back to the appropriate leaf stage for the particular time of year.

If a lot of pasture remains after grazing, there will be old, decaying leaves by the next grazing.

If pastures get tall, they contain old, decaying leaves and, in spring and summer, lots of stem. In addition, clover and young ryegrass tillers will be shaded out, resulting in less leaf material in the future.

The Feeding Pastures For Profit program is highly recommended for those seeking to improve their grazing management skills.

For more information search for 'Feeding pastures for profit'.

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Grazing management affects intake

Successful grazing management is all about ensuring maximum intake. The table below shows the conditions under which cows will eat more pasture.

Pasture is easy to graze	Harvesting short pasture is hard work, so make sure there is reasonable length (10–15 cm). Pastures that are too tall might be easy to graze, but their regrowth and quality are likely to be severely compromised.
Pasture is leafy	Leaf is the most easily digested part of the plant and has the most energy and protein.
Pasture is free of stem	Stem is harder for a cow to graze; it is tougher than leaf and harder to bite off. Stem contains less digestible nutrients than leaf and is broken down slowly. Stemmy feed remains in the rumen for a longer time before moving on to the small intestine.
Pasture is free of decaying material	Cows tend to avoid dying and dead material. Cows eat less if the pasture contains decaying leaves and stem, and its nutritive value will be lower anyway.
Pasture is full of clover and ryegrass	These are the most nutritious pasture species. Cows find them very palatable.
Pasture is just the right height	Avoid requiring cows to graze below the previous height of grazing (or cutting). Pasture below this height contains dead or decaying matter plus lots of stem: not good for high production. Leave pasture in the recommended condition to ensure good grazing next time.
Dung patches are managed carefully	Clumpy patches are not palatable and can cause shading. Options include mowing/ topping, using other stock to eat the clumps and closely matching the available pasture with the cow's requirements.

NUTRITIVE CHARACTERISTICS OF PASTURE

The key factors that influence the nutritive characteristics of pastures are the:

- pasture species and composition of the sward
- time of year and stage of maturity.

Nutritive characteristics of pasture vary between regions. While it is often possible to obtain values from research conducted in a particular region, taking a sample and getting a feed analysis report is best practice.

This helps build up a credible body of evidence about current intake and is the first step in creating a balanced diet.

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Values for nutritive characteristics in published tables are usually for pasture cut to ground level. Remember, they do not reflect what the cow has actually consumed due to selection of nutrients by grazing cows.

Cutting pastures to ground level in research ensures that samples are harvested in a consistent manner, and that the values for nutritive characteristics are comparable. See p12.15 for further information.

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Nutritive differences – pasture species

Although the differences in the energy levels of pasture species may seem small, they have a big impact on milk production.

White clover	ME and crude protein of white clover is generally higher than ryegrass for most of the year, regardless of the time since the last grazing.
Ryegrass	Under rain-fed conditions, ryegrass growth rates are very low in summer and quality is lower for ME and CP compared with irrigated pasture. Ryegrass tends to accumulate high proportions of dead material in summer, even under irrigation, principally because of its intolerance of hot weather. This lowers ME and CP values compared to spring pastures.
Paspalum	The nutritive characteristics of paspalum are typical of those expected of a sub-tropical grass species. Values are poorer than ryegrass and clover.
Annual vs perennial	Irrigated annual pastures, which often consist of subterranean clover, Persian clover or annual ryegrass, have higher ME, crude protein and lower NDF concentrations than equivalent perennial species. This is partly because their main period of growth (April to October) avoids the hot weather. Of annual species, Persian clover is the one most likely to have the most extreme levels of ME (> 12 MJ/kg DM), crude protein (> 25%) and NDF (< 30%).

The table below shows how pasture quality can be influenced by plant species in the sward.

Nutritive characteristics of individual pasture species			
Species **Early vegetative stage**	**ME** **Metabolisable energy MJ/kg DM**	**CP** **Crude protein %**	**NDF** **Neutral detergent fibre %**
Perennial ryegrass	7.9–10.9	8–18	52–65
White clover	9.3–11.2	18–28	28–40
Paspalum	7.4–9.3	8–15	62–70
Source: Stockdale 1999.			

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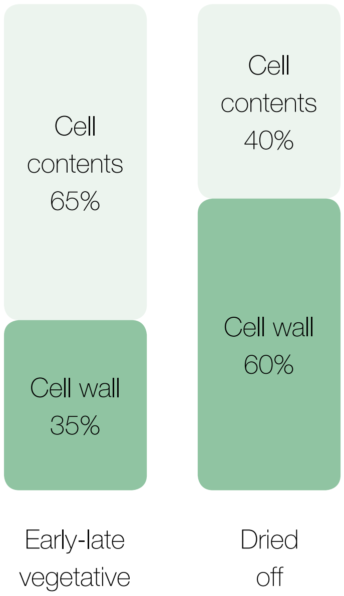
NUTRITIVE VALUES

There is a considerable body of information available on the nutritive characteristics of pastures used for dairying in Victoria.

All available information for energy, protein and fibre in the three major dairy regions of Victoria has been collated into computer databases which can be accessed by researchers, advisers and farmers. Search for 'Annual and Perennial Pastures Databases'.

Information on minerals can be found in Jacobs JL, Rigby SE (1999) Minerals in Dairy Pastures in Victoria. Department of Natural Resources and Environment: Warrnambool, Vic.



Source: Adapted from Pond WG, Church DC, Pond KR (1995) Basic animal nutrition and feeding.

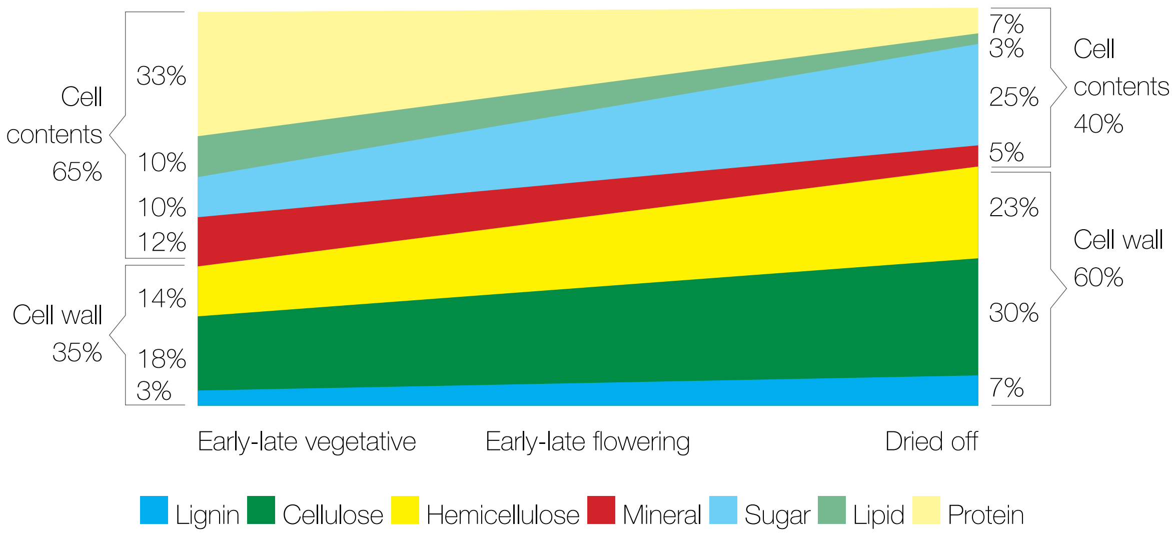
Time of year and stage of maturity

The nutritive characteristics of a pasture sward vary with the region, the time of year and the stage of maturity of the dominant pasture species.

Generally, when the dominant species matures, and this applies particularly to grasses, the quality or nutritional value declines. The highly digestible leaf becomes a smaller and less digestible portion of the whole plant. The proportions of structural cell wall carbohydrates (cellulose and hemi-cellulose) and lignin increase. Protein decreases with advancing maturity, while the concentration of sugars may increase. Variation in nutritional value is also related to the growing conditions needed for the different pasture species. For example, white clover grows well in the warmer conditions of spring/summer.

When the dominant species begin to mature, the quality or nutritional value declines. This applies particularly to ryegrass.

EFFECTS OF STAGE OF MATURITY ON PASTURE COMPOSITION DURING SPRING



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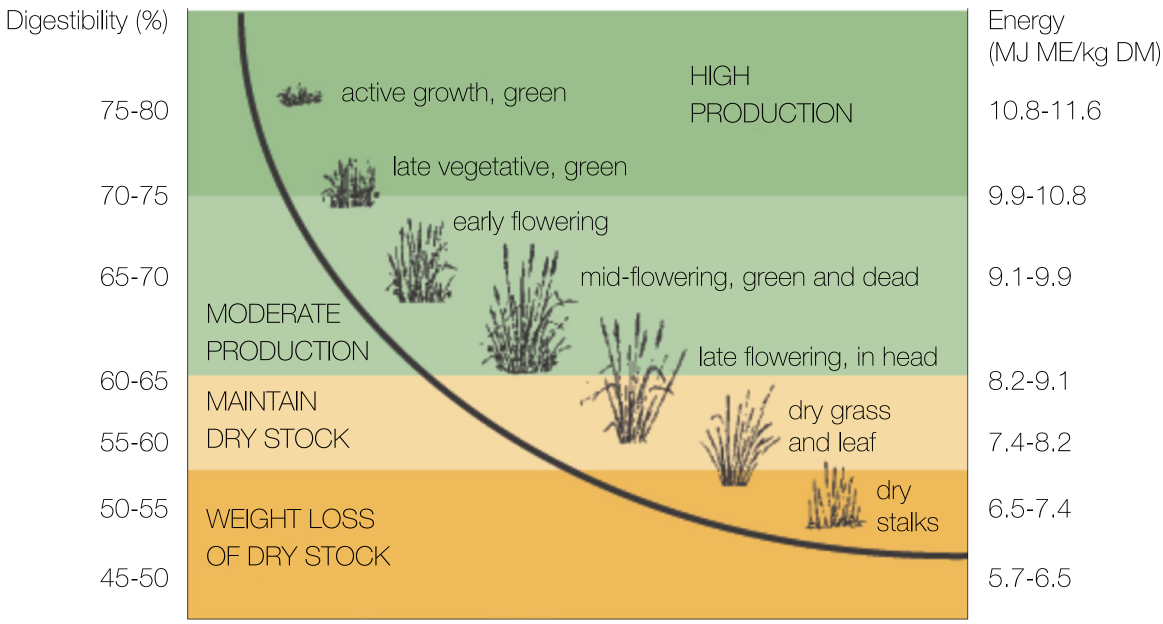

Source: NSW PROGRAZE® Manual, NSW Agriculture.

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Energy and protein levels typical of paspalum-dominant pasture. Note that in spring, paspalum is still quite leafy and so nutritive values are higher at this time		
Season	**ME Metabolisable energy MJ/kg DM**	**CP Crude protein %**
Spring	10.4	17.3
Summer	8.9	13.2
Autumn	9.1	14.4
Source: Stockdale 1999.		

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Energy and protein levels typical of perennial ryegrass-dominant pasture in northern Victoria		
Season	**ME Metabolisable energy MJ/kg DM**	**CP Crude protein %**
Spring	12.5	22.4
Summer	11.7	16.1
Autumn	11.6	18.6
Source: Annual and Perennial Pastures Database.		

PASTURE SELECTION – WHICH END OF THE RANGE SHOULD I USE?

Feed analysis is the best way to assess the nutritive characteristics of a feed. The reality is that many advisers use feed nutrient tables, particularly when doing 'back of envelope' calculations.

Feed nutrient tables often have values presented as a range and it can be difficult to know which end of the range to base calculations on.

To choose the right end of the range, keep the following general principles in mind and consider selection factors for energy, protein and NDF, as per the tables on the following pages.

On average, cows select 5–15% more metabolisable energy than is on offer. They select 24–40% more crude protein and 5–25% less neutral detergent fibre.

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Remember, feed analysis samples are cut to ground level to remove sampling subjectivity but cows do not eat to ground level.

Cows pick out what they like and eat less of what they don't like.

Cows do not like soiled pastures, mature pastures or weeds and will selectively graze clover and young succulent grass.

Cows will choose to eat more leaves and less stems.

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Selection factors for energy

The energy content difference between leaf and stem is relatively small and consequently selection factors are correspondingly small.

High-quality pasture (e.g. spring / autumn, perennial ryegrass, white clover)		**Low-quality pasture (e.g. paspalum, weed-infested)**	
High post-grazing residuals (>8 cm)	Low post-grazing residuals (<4 cm)	High post-grazing residuals (>8 cm)	Low post-grazing residuals (<4 cm)
+ 15% ME	+ 5% ME	+ 5% ME	As per feed analysis

EXAMPLE: SELECTION FACTOR FOR ENERGY

Cows are grazing a high-quality spring pasture and are leaving high residuals: the grazing allowance is too high.

The selection factor for energy would be at the high end of the range: plus 15% ME.

The feed analysis estimates pasture ME at 11 MJ ME /kg DM.

The pasture as eaten by the cows will have an estimated energy content of:

- **11 x 15/100 = 1.6 (additional ME selected)**
- **11 + 1.6 = 12.6 MJ ME/kg DM eaten.**

Selection factors for protein

Concentrations of protein differ markedly between leaf and stem in white clover, ryegrass and paspalum. Leaves predominate in the upper canopy, where the cow mostly grazes.

Selection factors for protein are correspondingly high at plus 25–40% on both rain-fed and irrigated pastures.

Green pasture	
High post-grazing residuals (>8 cm)	Low post-grazing residuals (<4 cm)
+ 40% CP	+ 25% CP

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EXAMPLE: SELECTION FACTOR FOR PROTEIN

Cows are grazing a high-quality spring pasture and are leaving high residuals: the grazing allowance is too high.

The selection factor for protein would be at the high end of the range: plus 40% CP.

The feed analysis measures pasture CP at 28% CP.

The pasture as eaten by the cows will have an estimated protein content of:

- **28 x 40/100 = 11.2 (additional CP selected)**
- **28 + 11.2 = 39% CP eaten.**

Selection factors for NDF

There is significantly less NDF in the leaves of pasture than in the stems.

Green pasture	
High post-grazing residuals (>8 cm)	Low post-grazing residuals (<4 cm)
- 25% NDFt	- 5% NDF

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EXAMPLE: SELECTION FACTOR FOR NDF

Cows are grazing a high-quality spring pasture and are leaving high residuals: the grazing allowance is too high.

The selection factor for NDF would be at the high end of the range: minus 25% NDF.

The feed analysis measures pasture NDF at 40% NDF.

The pasture as eaten by the cows will have an estimated NDF content of:

- **40 x 25/100 = 10 (less NDF selected)**
- **40 – 10 = 30% NDF eaten.**

ESTIMATING PASTURE INTAKE

In systems where pasture plays a role, creating an adequate and balanced diet depends on the ability to estimate pasture intake. This is not always easy to do.

Nutrient intake from grazing can be difficult to estimate due to sward characteristics and cows' selective grazing behaviour.

Nutrient balancing is difficult without an ability to predict nutrient and dry matter intake from grazed herbage.

Without relatively accurate knowledge of nutrient and dry matter intake, recommendations on the use of formulated concentrates are difficult to get right.

When estimating pasture intake, it is advisable to build up a body of evidence about what intake is likely to have been.

Use a systematic approach to evaluating pasture in the paddock pre- and post-grazing.

Don't forget to adjust nutritive values by applying a selection differential.

Estimation of pasture intake can be achieved by two different methods:

- direct measurements of the sward
- working backwards from milk production using computer programs.

Whatever method is used, it is important to remember that the aim is to build estimates on an integrated body of evidence which takes account of sward characteristics including mass and allocation and the reality of selective grazing.

!

Around 30–45% of the variation in operating profit in non-irrigated dairy farms in southern Australia can be attributed to the consumption of home-grown feed.

Chapman DF, Kenny SN, Beca D, Johnson IR (2008) Pasture and forage crop systems for non-irrigated dairy farms in southern Australia.

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Direct measurements of the sward

Pasture mass can be estimated using:

- a rising plate meter
- pasture probes
- visual assessment
- sensors on quad bikes.

The daily amount of pasture consumed by a herd can also be obtained from the difference between pre- and post-grazing pasture masses.

The accuracy of such estimates depends on taking sufficient readings to overcome the inherent variation in pasture mass across a sward, and on the availability of appropriate calibration data.

All approaches to measuring pasture mass require robust calibration because, at any given reading, there is considerable variation in measured mass. This is due to variations in species composition, leaf-to-stem ratios and the amount of dead material in the sward. This approach results in short-term or daily estimates of pasture intake.

Although pasture intake can be estimated from automated measurements of pre- and post-grazing pasture mass in strip-grazing or small-paddock rotational grazing systems, such methods have not been widely adopted.

AN ALTERNATIVE APPROACH IS TO PREDICT SHORT-TERM INTAKE FROM:

- descriptions of the pasture
- supplementary feeding practices
- level of milk production using decision support tools.

Decision support tools incorporate known principles of energy metabolism and use information on activity, maintenance, milk production, pregnancy and changes in body tissue. For more information, search Diet Check Agriculture Victoria.

Working backwards from milk production using computer programs

Estimation of pasture consumed on an annual basis can also be obtained by a range of back-calculation methods.

Back calculation of daily pasture intake for the purposes of diet balancing can be fraught with danger.

If close attention is not paid to the entire body of evidence (including cow observations and past grazing residuals), the result of the back calculation could vary greatly from reality.

Many methods of back calculation of pasture consumption do not adequately account for the ME requirements of grazing cows within modern dairy farming systems.

The estimated amount of pasture consumed on an individual farm can vary between 8 and 12 t DM/ha depending on the assumptions and detail used within the method described.

The most common outcome of poor pasture intake estimations is excessive weight loss in early lactation: what has been assumed to be coming from pasture is actually coming from condition loss.

!

PASTURE CONSUMPTION AND FEED CONVERSION EFFICIENCY CALCULATOR

This tool is designed to provide a robust, transparent and scientifically sound approach to estimating annual pasture consumption on-farm (in t DM/ha) which can be applied across the spectrum of grazing and supplementary feeding systems employed on Australian dairy farms.

The primary purpose of estimating pasture consumption in this manner on the farm or milking area is to benchmark performance of the farm over time.

The program is based on the generalised equations of ruminant requirements for ME for the various physiological processes published by CSIRO (2007) and differs from other approaches that do not fully account for ME requirements. For more information, search for DEDJTR pasture consumption calculator.

PROCESS FOR ASSESSING PASTURE INTAKE & CURRENT DIET

Use the following steps (full details are provided on a separate sheet) to determine pasture intake.

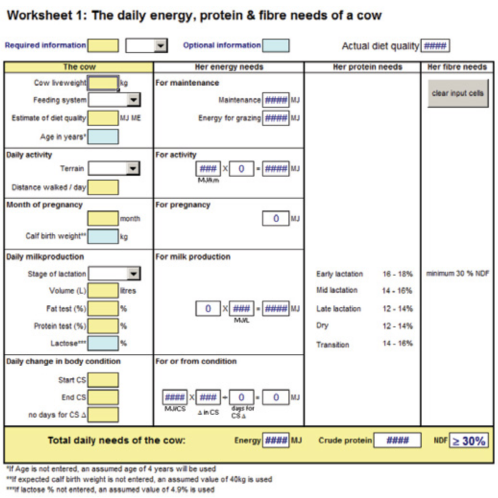
Step 1: Assess the cows
What can physical indicators tell about intake?

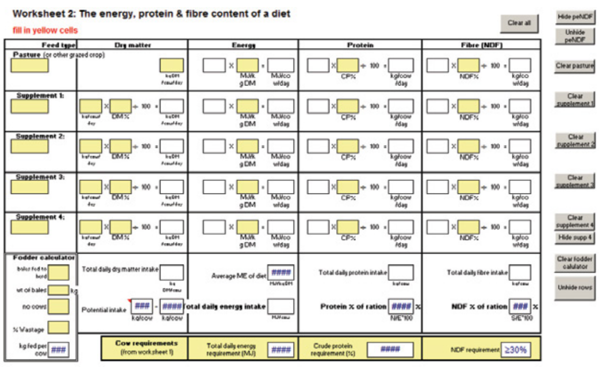
Step 2: Assess the pasture
Look at pasture availability, quality and post-grazing residuals.

Step 3: Run the numbers
Use worksheets 1 and 2.

Step 4: Check the numbers using the gathered body of evidence
Is the back calculation realistic?

See p. 12.29: Process for assessing pasture intake & the current diet
See p. 12.30: The Worksheet 1: The Daily energy, protein and fibre needs of a cow
See p. 12.31: Worksheet 2: The energy, protein and fibre content of a diet





REFERENCES & FURTHER READING

The Feeding Pastures for Profit program is highly recommended for those seeking to improve their grazing management skills. Search: Feeding Pastures for Profit.

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PROCESS FOR ASSESSING PASTURE INTAKE & THE CURRENT DIET

Step 1: Assess the cows

What can physical indicators tell us about intake?

- Rumen fill
- Manure consistency
- Cow's demeanour - are they content?
- Rumination
- Condition score

Step 2: Assess the pasture

Pasture availability

- Pre-grazing mass
- Post-grazing mass
- Area allocated (24 hours)

Pasture quality

- Visual assessment of species mix in sward
- Visual assessment of maturity
- Feed analysis:
  - test actual sward
  - use previous results from similar pasture
- Selection differential – how much better quality will the cows choose than the average of the sward?

Pasture signs

- How hard are the cows grazing?
- Does the post-grazing residual indicate that cows are hungry (over-grazing) or that they are being offered too much (under-gazing)?

Step 3: Run the numbers

Cow requirements

- Calculate current cow requirements for ME, CP and NDF using worksheet 1

Feeds other than pasture

- What feeds other than pasture are being fed?
- At what rates are these feeds being fed?
- What level of wastage is occurring?
- What is the quality of the feeds?

Back calculate the diet using worksheet 2

- Enter feeds other than pasture into worksheet 2
- Assume the rest of the cows' energy requirements (MJ ME) are being met by the pasture
- Using the assessment of pasture quality already established, calculate the amount of pasture needed to meet cows' requirements

Step 4: Check the numbers using the gathered body of evidence

Is the back calculation realistic?

Check against intake limitations: can the cow eat that much?

- Mertens equation, % live weight

Check against pasture availability assessment

- Does the back calculated allocation match the assessed allocation?

Check against pasture signs

- Over-grazing or under-grazing?

Check against cow signs

- Do the cow signs suggest the cows are looking for more feed or that they are being offered as much or more than they can eat?

Adjust the existing diet to reflect the body of evidence

Determine the adequacy of the existing diet and calculate changes in diet as required

Worksheet 1: The daily energy, protein and fibre needs of a cow

The cow	Her energy needs	Her protein needs	Her fibre needs
Cow liveweight **A** Grazed / Non-grazed ____ kg Est Diet quality ____ MJ	For maintenance **J** ____ MJ	Early lactation 16–18% Mid-lactation 14–16% Late lactation 12–14% Dry 12–14% Transition 14–16%	Minimum 30%(NDF)
Daily activity level **B** Terrain: Flat / Undulating / Steep ____ km/day	For activity **K** ____ X ____ = ____ MJ Distance (from B) / MJ/km		
Month of pregnancy **C** ____ *th* month	For pregnancy **L** ____ MJ		
Daily milk production **D** Volume ____ litres **E** Fat test ____ % **F** Protein test ____ %	For milk production **M** ____ X ____ = ____ MJ volume (from D) / MJ/L		
Change in body condition **G** Start CS ____ Loss - / Gain + **H** End CS ____ **I** no days for Δ ____	For or from condition **N** ____ x ____ ÷ ____ = ____ MJ per CS / Δ CS (H – G) / days for Δ (from I)		

Total daily needs of this cow:

Energy ____ MJ ($J + K + L + M \pm N$)

Crude protein ____ % (from above)

NDF fibre ____ % (from above)

Worksheet 2: The energy, protein and fibre content of a diet

Dry matter	Energy	Protein	Fibre
Pasture **A** ☐ kg DM /cow/ day	**F** ☐ X ☐ = ☐ from A; MJ /kg DM from feed test; MJ /cow/day	**J** ☐ X ☐ ÷ 100 = ☐ from A; protein % from feed test; kg/cow/day	**O** ☐ X ☐ ÷ 100 = ☐ from A; NDF % from feed test; kg/cow/day
Supplement 1: **B** ☐ X ☐ ÷ 100 = ☐ kg /cow/day; dry matter % from feed test; kg DM /cow/ day	**G** ☐ X ☐ = ☐ from B; MJ /kg DM from feed test; MJ /cow/day	**K** ☐ X ☐ ÷ 100 = ☐ from B; protein % from feed test; kg/cow/day	**P** ☐ X ☐ ÷ 100 = ☐ from B; NDF % from feed test; kg/cow/day
Supplement 2: **C** ☐ X ☐ ÷ 100 = ☐ kg /cow/day; dry matter % from feed test; kg DM /cow/ day	**H** ☐ X ☐ = ☐ from C; MJ /kg DM from feed test; MJ /cow/day	**L** ☐ X ☐ ÷ 100 = ☐ from C; protein % from feed test; kg/cow/day	**Q** ☐ X ☐ ÷ 100 = ☐ from C; NDF % from feed test; kg/cow/day
Supplement 3: **D** ☐ X ☐ ÷ 100 = ☐ kg /cow/day; dry matter % from feed test; kg DM /cow/ day	**I** ☐ X ☐ = ☐ from D; MJ /kg DM from feed test; MJ /cow/day	**M** ☐ X ☐ ÷ 100 = ☐ from D; protein % from feed test; kg/cow/day	**R** ☐ X ☐ ÷ 100 = ☐ from D; NDF % from feed test; kg/cow/day
Total daily dry matter intake **kg DM/cow** **E** ☐ A+B+C+D	Average energy density of diet MJ ME/kgDM ☐ U ÷ E	Total daily protein intake kg/cow **N** ☐ J+K+L+M	Total daily fibre intake kg/cow **S** ☐ O+P+Q+R
Potential daily intake kg DM/cow ☐ to ☐ When in milk: 0.03 x LW to 0.04 x LW When dry: 0.015 x LW to 0.02 x LW	**Total daily energy intake** **MJ/cow** **U** ☐ F+G+H+I	**Protein % of ration** ☐ N÷E X 100	**NDF % of ration** **T** ☐ S ÷ E X100

Cow requirements (from Worksheet 1)	Total daily energy requirement ☐ MJ	Crude protein requirement ☐ %	Fibre requirement ☐ % NDF

13 FEEDING COWS FORAGE & FODDER

Forage and fodder supplements include conserved fodder such as pasture hay and straw, pasture and crop silages, and standing crops specifically grown for grazing (like turnips).

Conserving surplus pasture and specialty crops can fill feed gaps by transferring high-quality feed from periods of surplus to times of deficit. It can also play an integral role in matching feed supply with requirements, improving pasture utilisation and management and improving the profitability of dairy farms.

For lactating cows, forage and fodder supplements can be useful as fibre sources, particularly in mixed diets.

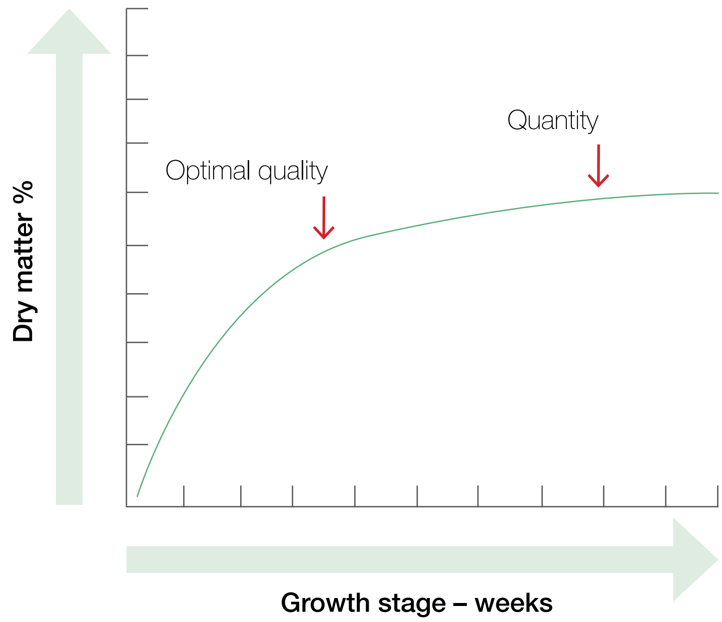
In dry cow diets, conserved fodder may be the sole ingredient of the diet.

Forage and fodder can take the place of pasture when pasture is in short supply.

Forage and fodder can help balance diets by providing additional fibre if fibre is inadequate.

ADVISER ALERT: QUANTITY VERSUS QUALITY

If you are producing fodder for milking cows, ensure that it is fit for purpose. Focus on cutting for quality not quantity.



Conserved forages are generally high in fibre. The need for fibre is a key reason for including hay or silage in a lactating cow's diet.

Conserved forages can also be valuable energy and protein supplements if not cut at too late a stage of maturity.

Higher energy and crude protein values tend to be found in early-cut hay and silage.

Late-cut hay and silage generally have lower energy and protein values.

If cut on the same day, silage is no higher in nutritive value than hay. Silage is only better than hay if the pasture is cut when it is less mature.

Hay and silage are often used as a sole feed for dry cows.

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NUTRITIVE CHARACTERISTICS OF FORAGE AND FODDER SUPPLEMENTS **VARY WIDELY**

A comprehensive list of supplement nutritive characteristics built from the FEEDTEST database from the late 1990s and the early 2000s is available for:

Dry matter (DM %)	Metabolisable energy ME (MJ/kg DM)
Crude protein (CP %)	Neutral detergent fibre (NDF %)

Note: this table contains **average** values and **ranges** for hay, straw, silage and forage crops.

Search for DEDJTR Dairy supplement list.

Want an accurate picture of the actual values cows are fed? A feed analysis test is best practice.

FEEDING HAY

The traditional supplement for dairy cows is pasture hay, conserved from excess pasture growth. If high-quality pasture hay can be made or purchased consistently, it can be fed to milking cows to overcome feed shortages. Low- or variable-quality hay generally results in poor milk production responses but can be used in small quantities. It is also suitable for dry or young stock.

Cereal straws can be conserved to be fed to dry cows as part of their transition diet. Apart from fibre, straw's main value lies in its mineral composition: it can have a role to play when attempting to combat milk fever. See Chs 19 and 21 for further details.

Using book values can be risky. A feed analysis test is the only way to really know what is being fed.

!

ADVISER ALERT

Failed grain crops like cereals or canola conserved as hay in dry years can be extremely variable in quality. Here are two examples.

Wheaten hay – range
1088 samples
ME MJ/kg DM: 6.4-12.6
Crude protein: 2.1-21.1 %
NDF: 37.3-70.3 %

Canola hay – range
708 samples
ME MJ/kg DM: 3.9-13
Crude protein: 5.9 – 27.7 %
NDF: 21.7 – 69.1 %

Source: FEEDTEST Samples from the 2007–08 season.

The range in nutritive values can be explained by the quality of the standing crop and harvest conditions. Leaf matter can shatter with mechanical processes like raking and baling.

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Nutritive characteristics of hay & straw								
Supplement type – hay & straw	Dry matter %		Metabolisable energy MJ/kg DM		Crude protein %		Neutral detergent fibre%	
	Average	Range	Average	Range	Average	Range	Average	Range
Barley hay	87	66.1 –93.7	8.8	4.2 –11.2	8.2	1.2 –14.6	57.8	42.0 –86.6
Barley straw	89.3	73.4 –93.6	6.5	2.2 –8.5	2.8	0.2 –28.8	76.5	54.7 –87.3
Clover hay (generic)	86.6	61.3 –93.2	8.9	6.2 –11.2	17.6	6.3 –26.1	46.9	33.2 –72.2
Legume plus grass mix hay - legume dominant	86.4	45.2 –95.9	8.8	5.2 –11.4	14.5	4.1 –25.4	53.6	30.4 –78.4
Lucerne hay	87.8	36.0 –96.1	9.3	5.3 –11.3	18.9	5.7 –29.7	44.7	30.9 –67.0
Lucerne straw	86.1	68.2 –93.4	5.7	4.3 –6.8	8.9	5.9 –14.1	66.5	64.7 –68.0
Oaten hay	88.9	40.2 –96.4	8.4	4.5 –11.3	6.9	1.1 –16.3	59.3	41.1 –83.6
Oaten straw	89.4	80.2 –93.8	6.2	4.3 –10.0	2.8	0.1 –11.9	73.3	54.5 –78.8
Pasture hay	86.2	48.6 –95.5	8.4	5.3 –11.2	10.8	1.7 –30.0	63	36.8 –81.7
Persian clover hay	85.6	67.8 –93.5	9.6	7.0 –11.7	16.2	5.3 –23.3	43.4	32.6 –66.8
Rice straw	85.2	52.2 –93.5	6.7	5.3 –8.9	4	1.9 –5.0	63.4	53.4 –68.5
Sub clover hay	86.8	71.7 –93.9	8.8	6.5 –10.6	17.2	7.7 –25.7	47.3	33.1 –71.0
Triticale hay	86.6	54.3 –93.9	8.6	4.8 –10.7	7.3	1.3 –16.2	55.7	40.5 –73.0
Triticale straw	89.8	62.7 –95.7	6.2	4.1 –9.0	2.8	0.7 –6.7	67.3	50.1 –86.5
Wheat hay	87.9	46.8 –95.1	8.7	4.9 –11.0	8.2	0.1 –17.4	52.8	37.3 –79.4
Wheat straw	92.4	64.7 –96.7	5.1	3.8 –9.3	2.8	0.2 –8.8	73	53.6 –86.2

Source: Search for DELWP Dairy supplement list

Successful Silage

For comprehensive information on producing high quality silage, search for Dairy Australia Successful Silage.

FEEDING SILAGE

In most Australian systems, silage is fed either as a supplement to pasture or as part of a partial or total mixed ration. Silages are often made from pastures but there is an increasing interest in maize and whole crop winter cereals.

The specialised silage crops produce one silage cut only, with little or no opportunity for any grazing.

Winter cereals are sometimes grazed before being shut up for conservation.

From a nutritional point of view, high-quality, well-preserved silage and high-quality pasture are essentially interchangeable.

Silage requires a shorter time for sun curing than hay, so it can be made with less risk earlier in the season when pasture quality is high.

Pasture silage is generally higher in nutritive value than hay. For this reason, milk responses to pasture silage should be better than from hay.

The degradability of protein in silages is usually high.

The digestibility of silage is the most important factor influencing the milk production response to silage.

Protein and mineral supplementation may be necessary if maize silage is a significant component of the diet.

Other crop silages in the low-protein category are grain sorghum, sweet sorghum and some whole crop cereals.

Aim for an ME content of 10 MJ/kg DM or higher.

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ADVISER ALERT

Cows may benefit from the addition of a source of undegraded dietary protein (UDP) when being fed silage.

As found in recent experiments at Ellinbank, due to higher degradability of protein in high-quality pastures and silages, a production response may be seen when some UDP is provided, even if the overall protein level in the diet appears adequate.

Silage is often preferred to hay because it generally has higher nutritive characteristics than hay, but only if cut at an earlier growth stage, ensiled and stored properly.

An acid fermentation occurs when moist forages are stored under anaerobic conditions.

During fermentation, bacteria convert plant sugars to fermentation acids and other compounds.

The fermentation produces mainly lactic acid and in sufficient quantity to quickly reduce pH. At low pH, acid conditions prevent further microbial activity and spoilage.

Silage will not deteriorate as long as anaerobic conditions are maintained. Aerobic spoilage begins as soon as it is exposed to air.

The first sign of spoilage is heating of the silage.

The nutritive value of silage depends on ensiling conditions: compacting, drainage and airtight storage must be adequate to result in a good fermentation.

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ADVISER ALERT: CHECKING FERMENTATION OF SILAGE

The pH of the silage confirms the extent of the fermentation: that is, how much of the sugars fermented into acid.

pH target is 4.0-4.7 (depends on silage DM content and forage type)

Ammonia N indicates the degree to which the protein in the forage has been degraded during the ensiling process.

Ammonia N as % total nitrogen target is less than 10%

When sending silage samples to a lab for testing, make sure you request analysis of their fermentation quality.

Determining the effect of wilting is difficult in many dairy experiments for the following reasons.

- Silage is often fed with concentrates, which can mask any differences between unwilted and wilted silages.
- Additives are often applied to the unwilted control silages to improve preservation. If the unwilted control silage is well-preserved, there is less likely to be an intake or production benefit from wilting.

Effect of wilting

A number of studies have investigated the effect of wilting on silage dry matter intake and milk production. In most studies:

- dry matter intake of wilted silages was higher than that of unwilted silages produced from the same forage
- the effect of wilting on milk production has varied, and a number of studies have shown no benefit.

Rapidly wilted, high-digestibility pasture silage will usually produce the best animal responses. The restricted fermentation and higher dry matter content of this type of silage will:

- sustain high intake
- minimise dry matter and quality losses during conservation if over-wilting is avoided
- usually leave more readily fermentable energy (as water-soluble carbohydrates) for fermentation in the rumen.

Effect of chop length

The effect of chop length on intake and milk production has been variable, with increased milk production in response to finer chopping being seen in about half the studies undertaken.

Reducing chop length can increase intake either directly or indirectly:

- directly, by reducing eating and ruminating time
- indirectly, by improving the silage fermentation.

ADVISER ALERT

Chopping reduces the effectiveness of the fibre in silage or hay.

If dietary fibre levels are high, chopping may be desirable to increase intakes and passage rate.

If dietary fibre levels are low, fine chopping may contribute to subacute ruminal acidosis.

Reducing the chop length is more likely to lead to an increase in intake when silage is the major component of the diet.

It is important to remember that the quality of the standing crop affects the quality of the conserved crop.

The quality of the conserved product will generally be lower, so aim to minimise quality losses during conservation.

Nutritive characteristics of silage								
Supplement type								
Silage	**Dry matter %**		**Metabolisable energy MJ/kg DM**		**Crude protein %**		**Neutral detergent fibre %**	
	Av.	Range	Av.	Range	Av.	Range	Av.	Range
Barley silage	39.0	20.9–64.3	9.1	5.5–11.5	10.7	5.5–22.9	60.8	44.5–68.9
Clover silage generic	41.9	20.9–79.5	9.6	8.1–10.6	19.3	12.4–27.2	46.3	38.6–56.1
Legume + grass mix legume dominant silage	42.1	13.7–68.3	9.4	5.9–11.4	16.0	7.3–28.6	50.8	28.6–76.2
Lucerne silage	49.5	15.8–87.7	9.4	4.8–10.9	20.0	5.3–32.1	45.5	27.3–63.7
Maize silage	30.9	9.2–84.5	10.6	5.0–13.0	7.7	3.4–17.1	48.2	36.4–67.1
Oaten silage	40.9	18.1–82.2	8.7	5.9–11.2	9.8	3.8–19.4	59.9	39.5–75.3
Pasture silage	43.1	10.9–87.6	9.4	2.2–11.8	14.1	3.2–27.3	56.5	31.8–79.5
Persian clover silage	42.9	23.7–81.9	9.9	8.2–11.2	17.6	8.0–23.4	47.6	34.7–60.0
Sub clover silage	37.1	20.6–59.9	9.5	5.2–10.5	18.8	12.6–26.9	45.6	30.6–59.2
Triticale silage	42.9	20.1–71.0	9.1	7.1–11.2	10.8	4.0–24.0	57.9	41.4–70.2
Wheat silage	44.9	27.5–69.1	8.8	4.6–10.7	10.0	6.5–16.0	55.5	47.7–63.4

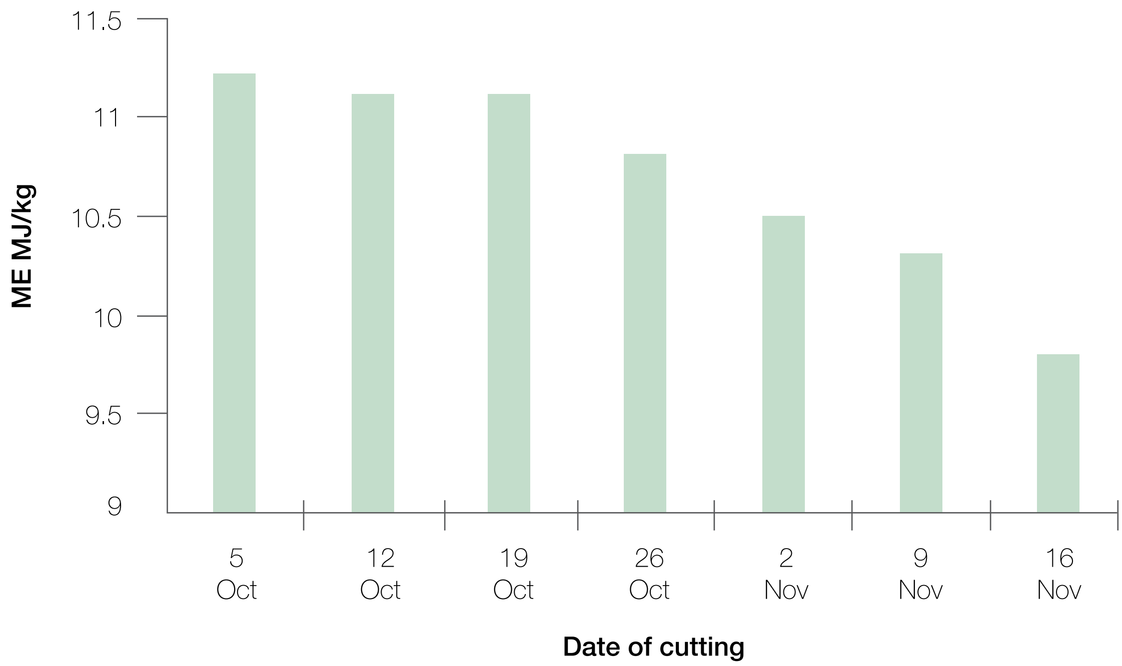
Source: DELWP Dairy supplement list.

Effect of stage of maturity

The stage of maturity of forages at conservation has a considerable effect on their ME values. The figure below provides an example of this.

Silage cut on 5 October contained 11.3 MJ/kg DM. At this time, perennial pasture was still in its vegetative, pre-flowering stage of growth. The ME remained above 11 MJ/kg DM until the last week of October. At this point, ear emergence occurred in the ryegrass fraction of the sward and energy values began to decline.

TYPICAL CHANGES IN NUTRITIVE VALUE OF SILAGE AS PASTURE MATURES



Source: Jacobs et al. 1998 - Pasture study conducted in western Victoria.

Pasture conserved too late in the season will be of little benefit to milkers because of its lower energy density.

With maize, this does not happen to the same extent because grain development in the ear tends to offset the decline in quality of the leaves and stalks. The quality of maize silage can be lifted by raising the cutting height at harvest. This increases the grain proportion of the silage.

Successful Silage TOPFODDER

For comprehensive information on producing high quality silage, search for Dairy Australia Successful Silage.

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MAIZE SILAGE

Maize silage is considered an excellent medium-energy supplement for dairy cows. The economic viability of maize silage is very dependent on yields and energy values.

Maize is generally expensive to grow: compare it to other options based on energy and protein per tonne of dry matter. The net cost/tonne DM might be attractive if ryegrass will not thrive in prevailing climatic conditions.

It requires good management to produce high yields that maintain good nutritive characteristics.

Maize silage has low protein and this fact needs to be considered when using it as a supplement.

Mineral supplementation may be necessary when maize silage is a significant component of the diet.

Unlike pasture silage, maize does not need to be wilted.

It is usually harvested with a precision-chop harvester.

The drier the crop at harvest, the finer the chop. This ensures good compaction and fermentation.

Potential yield and forage quality of maize forage cut at MLS 2 to 3

Growth stage (MLS)	ME (MJ/kg DM)	Crude protein (%DM)	Potential yield (t DM/ha)
MLS 2–3	10–11	4.5–8.5	12–25

Harvesting maize close to the ground will maximise herbage yields but raising the cutting height improves its quality. This results in a proportional increase in grain content.

Raising maize silage cutting height from 15 cm to 45 cm can reduce yield by up to 15% but it increases digestibility by 2 percentage units. This reduces the stem to leaf/cob ratio.

WINTER CEREAL CROP SILAGE

Oats, wheat, barley, triticale and cereal rye can all be made into silage. Winter cereal crops can be harvested at three distinct growth stages:

- late vegetative or boot stage
- flowering stage
- dough grain stage.

There is no one best time to harvest winter crops. At each growth stage a compromise between quality and yield has to be made. Early harvest produces maximum animal production per tonne of silage. Later harvest produces maximum production of dry matter per hectare.

At the mid-dough stage, winter cereals may be direct harvested, although wilting of the forage is essential if the dry matter of the standing crop is greater than 30%.

As winter cereals mature, the stems become hollow, which may affect compaction. The problem can be minimised by chopping to 10 mm lengths or by baling at the lower end of the dry matter range.

The effects of growth stage on potential yield and the nutritive characteristics of winter cereal silage are shown in the table below.

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Guidelines on the optimum growth stage for the various cereals other than oats are based on limited research that examined only a small sample of available varieties.

The effect of growth stage on the nutritive characteristics of winter cereal silage

Growth stage	Metabolisable energy MJ/kg DM	Crude protein % DM	Potential yield t DM/ha
Late vegetative or boot	9.5–10.5	8–18	1.5–7.0
Flowering	9.0–9.5	6–12	3.0–11.0
Dough grain	8.0–9.5	4–10	3.5–15.0

Source: p. 122 Dairy Australia: Successful Silage.

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During fermentation in the ensiling process, some of the true protein in pasture silage may be converted to non-protein nitrogen.

As a result, the level of UDP supplied to the cow may be reduced.

Protein concentration fall

Protein concentration falls as the winter crops mature. This is the case with all cereals.

Protein concentration can be improved by sowing with a legume.

Early-sown cereal/legume mixtures can include a clover and may be grazed.

Later-sown crops can include field peas or vetch but are suitable for one harvest only.

Oats tend to have lower protein concentrations than wheat or barley.

Oats should always be cut at an early growth stage – between boot and ear emergence – to preserve protein.

Low protein concentration is the major feed quality limitation of winter cereal silage, particularly when crops are harvested late at the mid-dough growth stage.

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PROTEIN CONCENTRATION MAY BE IMPROVED BY GROWING LEGUMES SUCH AS ANNUAL CLOVERS, FIELD PEAS OR VETCH WITH THE WINTER CROP

The degree of improvement will depend on the proportion of legume to winter cereal, with a legume component of 40–50% needed to make a reasonable difference.

Note however that a legume component is likely to lower the dry matter and water soluble carbohydrate concentrations of the resulting silage. It will also increase the requirement for wilting, particularly if the legume proportion is greater than 50%.

For details about the measurement of nitrogen components and pH specific to silage see Successful Silage - Top Fodder p. 123. Search for Dairy Australia Successful Silage.

Varying winter crop digestibility

Digestibility varies in different winter crops.

The decline in digestibility of oat crops is rapid with advancing maturity.

In contrast, the digestibility of wheat and barley crops increases to some degree as grain filling commences.

Silage digestibility % DM
Analyses undertaken by a feed testing laboratory over a 5-year period, 1996–97 to 2000–01

Silage type	Ave.	Range
Legume	66.7	46.1–76.3
Legume/grass	66.3	42.9–77.1
Grass/legume	66.1	39.9–80.2
Grass	64.9	48.0–76.7
Cereal	62.4	43.8–76.7
Cereal/legume	62.9	43.3–74.8
Maize	69.1	50.6–78.0

Source: Dairy Australia: Successful Silage.

For information on integration of forage crops into a farming system

Search for *Dairy Australia Project 3030* and *Future dairy*.

FEEDING FODDER CROPS

Fodder crops are used to fill feed gaps when pasture is lacking in quantity or quality. They can generally be grazed multiple times.

Fodder crops are an important supplement to pastures, particularly during summer and autumn. Fodder crops can be sown in autumn to fill the winter feed gap. Fodder crops such as sorghum and millet make reasonable feeds when grazed but if left to grow for silage they are low in energy and protein.

Annual ryegrasses can be sown as a fodder crop because they are well-adapted to grazing by cattle

Some forage crops (such as sorghum) can be toxic at certain stages of development. Get expert advice on grazing management prior to sowing.

Leading crop characteristics

Turnip crop	Maize crop	Oat crop
• High in energy • Can be used like a concentrate relatively cheap to grow, can yield 7–9 t DM/ha when sown in mid to late October • Fibre content may be low • Could be insufficient fibre and protein levels in the total diet if fed with a cereal grain • Trials at Ellinbank indicate that the protein content of turnips may be borderline • Feeding cottonseed meal (a high-protein feed) with grazed turnips gave a better milk yield response than grazed turnips alone	• Has low protein and mineral content: keep in mind when balancing diets • Can be eaten as a green crop (green chop) or made into silage • In southern Victoria the time required before the crop can be harvested (late April) means pasture resowing is delayed	• Can be grown as a fodder crop for winter feed but not well-adapted to grazing • Common practice is to over-sow paddocks with an annual ryegrass/oat mix

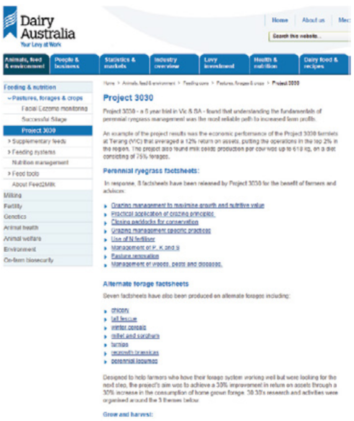
The nutritive characteristics of commonly grown fodder crops in Victoria						
Fodder crop	Dry matter %	Energy MJ/kg DM		Crude protein % of DM		NDF % of DM
		Ave.	Range	Ave.	Range	
Turnips, whole	10	13	11–13	11	6–18	22
Turnips, leaf	9	12	4.5–11	14	8–20	24
Turnips, root	11	13	13–14	9	6–15	21
Sorghum	18	9	7–11	12	7–18	40–60
Oats, immature	16	10	9–12	21	20–24	46
Typical annual ryegrass	16	11	9.5–11	22	18–24	30–45
Rape	14	12	–	20	–	30
Pasja	14	13	–	20	–	30
Millet	18	9	–	11	–	40–60
Maize, tassel stage	19	10	–	11	–	50
Oats, flowering	23	9	–	8	–	60

Source: Joe Jacobs DEPI – Warrnambool.

Future Dairy
www.futuredairy.com.au

Successful Silage
Top Fodder extension program
www.dairyaustralia.com.au

Project 30:30 Fact Sheets, search for Dairy Australia Fact Sheet Perennial Ryegrass & Alternative Forages.



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FEEDING COWS SUPPLEMENTS

In addition to hay and silage supplements sourced from off-farm, there are three other categories of supplements:

- energy concentrates, which include grains, seeds, pelleted concentrates, by-products or fat supplements including vegetable oils
- protein concentrates, which include grain legumes and vegetable protein meals
- high-fibre by-products (often called forage extenders), which include almond hulls and palm kernel expeller (PKE) meal.

Concentrate supplements can supply additional energy, fat and protein, but they can also be sources of fibre, vitamins and minerals.

ADVISER ALERT

It is easy to assume you know how much grain cows are actually eating when being fed in the dairy at milking times but it is not uncommon for individual feeders in a herringbone dairy shed to be out by at least 1 kg when dispensing 4–5 kg of grain.

In-shed feeding systems are based on volume, not weight. If the density of a load of feed is different from the previous load, the feeders will need to be adjusted in order to deliver the desired amount of grain.

It is recommended that in-shed feeders be checked at regular intervals as the variability in grain dispensing has the potential to cause acidosis. If acidosis does occur, and only a few cows are affected, check the feeders before doing anything else.

Energy concentrates

Feeds with large quantities of starches and sugars (like cereal grains, fats and oils) and some by-product feeds (like molasses) are used as energy supplements. Wheat, barley and triticale are the most commonly fed cereal grains.

Specially formulated commercial concentrate pellets, mixes, or by-products are also manufactured.

The energy content of most cereal grains is fairly consistent. Oats and sorghum are an exception.

Most cereal grains are low in calcium. Keep this in mind if feeding high grain levels during early lactation when milk fever is a potential problem.

By-products can be extremely variable in their composition, even from one batch to the next.

Many tables of feed composition report only the averages.

When developing diets, it is important to know the nutritive characteristics of the individual feeds that make up the total diet.

It is best to have feed ingredients analysed, preferably before purchase.

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Nutritive characteristics of energy-rich supplements: cereal grains, pellets and by-product feeds

Cereal grains	Dry matter %	Energy MJ/kg DM	
		Average	Range
Barley	90	12	12–14
Wheat	90	13	12–14
Oats	90	11	9–13
Triticale	90	12.5	12–13
Maize	90	13.5	12–16
Sorghum	90	11	7–13
Steam-treated sorghum	90	12	9–14

Pellets	Dry matter %	Energy MJ/kg DM	
		Average	Range
Commercial pellets	90	12	11–13

FACTORS AFFECTING MILK RESPONSE TO ENERGY CONCENTRATES:

Amount of pasture & supplement fed

Poor responses to supplements are recorded when daily pasture allowances are high. As the amount of supplement increases, diminishing marginal milk production responses will eventually result.

A key reason for these responses is an increasing level of substitution as the feeding level increases, but this only goes some of the way towards explaining the diminishing returns response.

Better-fed cows will put increasing amounts of energy into improving their body condition whereas underfed cows invariably use body condition to help maintain milk production, particularly in early lactation.

This is referred to as diminishing returns, and the curvilinearity of the response will eventually come into play at some level of feeding.

FACTORS AFFECTING MILK RESPONSE TO ENERGY CONCENTRATES:

Stage of lactation & quality of pasture

Until recently, accepted theory has been that additional ME in early lactation will result in greater immediate marginal milk production responses than an equivalent amount of additional ME fed in mid or late lactation.

While this principle may hold in TMR systems, it may not be the case in grazing systems. In both Victoria and New Zealand, marginal milk production responses have sometimes been higher in mid and late lactation.

Many of the lowest immediate milk responses are recorded in spring when many cows in S.E. Australia are in early lactation. It has been suggested that immediate marginal milk responses to cereal grain supplements are inversely related to the ME concentration of the pasture consumed.

The amount of NDF in the diet in spring may be low enough to impair rumen fermentation and, if this could be alleviated, improved responses could follow. This is because high-quality pastures sometimes contain so little dietary fibre that feeding large amounts of concentrates, say more than 4–5 kg/day, could lead to sub-clinical acidosis or even reduce milk fat concentration.

Best milk responses are seen in summer and autumn when the energy density of pastures is low because of the increasing amounts of structural carbohydrates (fibre).

Note that research has shown no effect of pasture quality on changes in body condition score when energy supplements were fed.

This suggests a reduction in the efficiency of use of ME with good-quality pasture. This is most likely associated with low effective fibre leading to reduced rumen pH impacting on digestion efficiency.

See appendices on pp 16–18: Marginal milk response for results on Australian grazing feeding experiments, New Zealand and Ireland results and indoor feeding experiment results.

Note that immediate marginal milk responses attributed to concentrate supplements can be extremely variable.

RESPONSES TO ENERGY SUPPLEMENTS

When energy supplements are fed to grazing dairy cows marginal milk responses vary considerably.

Marginal milk responses

Milk response to energy supplements varies. Concentrate substitution affects pasture intake and other factors influence the response, including the stage of lactation, the quality and interaction of the supplement and pasture on offer and the stocking rate.

When energy supplements are fed, or their amount changed, two responses relating to milk production occur:

- an immediate marginal milk production response: this is seen at the time the change in feeding occurs
- a long-term response: this takes into account the body condition that has been gained or lost at the time of feeding.

The size of these responses has a major impact on feed conversion efficiency. See Ch 23 for more information.

Immediate marginal milk responses

The factors affecting responses to energy supplements are numerous and complex, but variability will be principally due to variations in:

- cows' genetic merit for milk production, current stage of lactation, milk yield and body condition score
- the amount and quality of pasture on offer
- the amount and quality of energy supplement and how it has been processed.

Marginal analysis of decisions about feeding dairy cows

Farmers work with many biological responses. For example, pasture growth responds to fertiliser or water inputs, and there is a milk response to supplementary feed inputs.

It is important to not confuse **average** response to an input (such as a supplementary feed) with the **marginal** response.

It is also important to understand the **law of diminishing return** to any input.

The marginal cost is the cost of the extra unit of input multiplied by the quantity of the extra unit of input.

The marginal return is the price of milk (fat and protein) multiplied by the marginal product (amount of extra milk) from an extra input.

The principle that should guide decisions about using any input on a dairy farm is that further increments of the input should be used up to the level where the extra return from an extra unit of input just equals the extra cost of that input.

This is called 'where the marginal cost equals the marginal return'.

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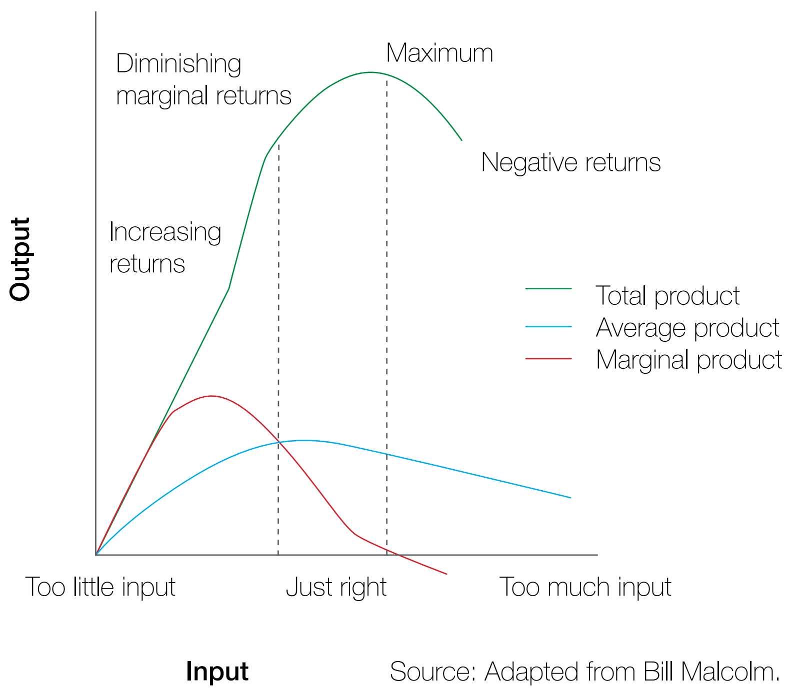
As the Total product line on the graph below shows, when the first few units of an input are added, the marginal return is high.

As additional units of the input are added, the marginal returns diminish, and at a given point further units of the input result in a negative return.

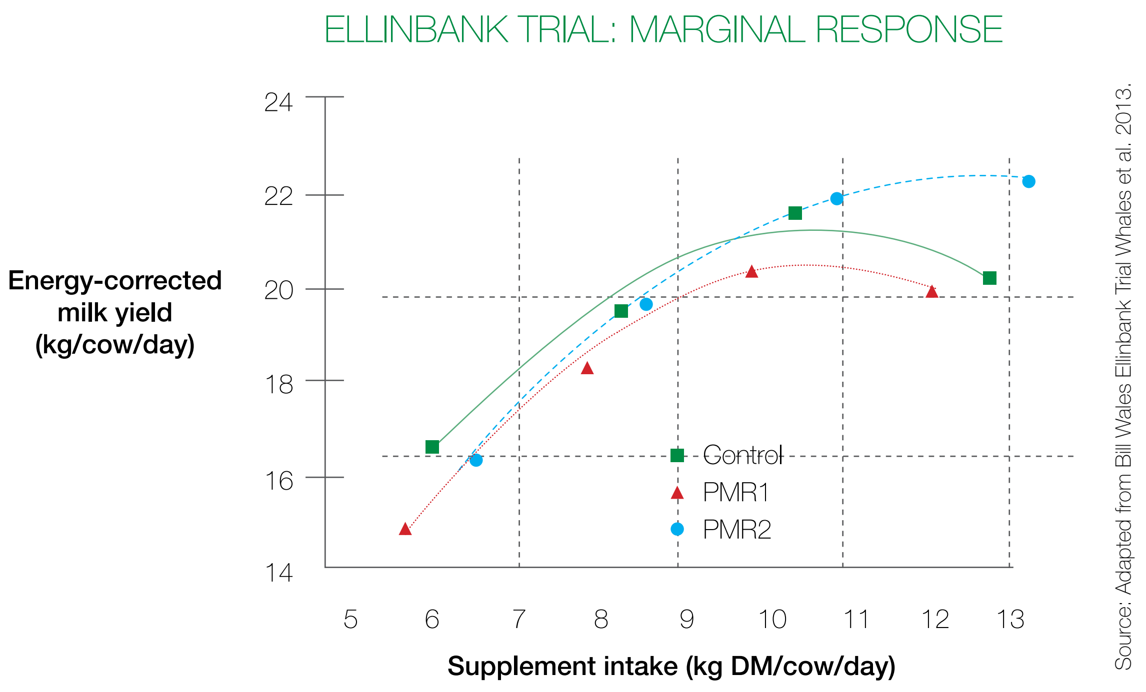
Note that if the input is an energy supplement, this may be due to creating ruminal acidosis.



Source: Adapted from Bill Malcolm.

An example

Three different supplements were fed in a feeding trial at Ellinbank. As expected, each has its own unique production response.



Note: control is wheat/barley grain fed in bale in slugs, PMR 1 is wheat/barley grain fed in PMR to spread slugs but till fast ferment, PMR2 is a corn component to spread fermentation profile.

As shown in the table below, the maximum marginal response for control and PMR1 supplements was reached at 10 kg DM per cow per day, whereas the maximum marginal response for PMR2 was not reached until 12 kg DM per cow per day.

Predicted marginal responses – kg Energy Corrected Milk (ECM) per kg DM supplement

kg DM	Control	PMR1	PMR2
7	1.6	1.6	1.9
8	1.1	1.1	1.5
9	0.6	0.6	1.1
10	0.0	0.1	0.7
11	-0.5	-0.4	0.3
12	-1.0	-0.9	-0.1

As a generalisation, total fat in the diet should not exceed 7%, with the fat coming from 1/3 plant source, 1/3 vegetable oil and 1/3 bypass fat.

Note that you might already be close to the ceiling if your pasture is already high in fat.

Most care is required when supplementing spring pastures which can be as high as 7% fat.

Fat supplements

Fat (or lipid) supplements include oilseeds (such as whole cottonseed and full-fat soybeans), vegetable oils and commercial fat products designed to pass through the rumen undigested. These products are absorbed in the small intestine and are called by-pass fats. Generally they are incorporated into cereal grain-based concentrate mixes to help increase milk yield, reproductive performance or feed efficiency.

Fats are concentrated forms of energy containing up to 35 MJ/kg DM.

Feeding fat has been shown to improve milk production, milk fat production and body condition. (Weiss and Pino-Rodriguez, 2009).

Milk responses to fat supplements vary widely, even for the same supplement. They can be in the order of 3 L of milk and 0.3% rise in fat test for each kg of fat consumed, although milk protein concentration may suffer. Factors which may influence responses include the type of fat supplement fed (fatty acid profile), the diet it is fed with, the stage of lactation when it is fed and its impact on dry matter intake (Rabiee et al, 2012). More research is required.

Fat supplements or lipid in supplementary feeds that are digested in the rumen can have a depressive effect on NDF digestion and dry matter intake.

Caution: bypass fat products

Some bypass fats are not fully rumen-inert and may contain polyunsaturated fatty acids (PUFAs) such as salts of palm oil.

If these products are used they can cause milk fat depression rather than an increase in fat test.

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Bypass fats

Bypass fats, which are digested in the small intestine, can be fed at higher levels without these side effects.

Bypass fats are a more expensive source of energy than grains.

They may be useful when fed during early lactation to high-yielding cows (greater than 30 L/day). These cows may otherwise lose weight so quickly that their fertility and metabolism may be upset.

Different commercial bypass fat products vary greatly in their fatty acid profile.

Note that there is an upper limit to the use of bypass fat due to the animal's limited ability to digest this fat in the lower digestive tract.

Judging the adequacy of a diet's fat level via percentage is risky. This is because of the interplay between the total intake of fat per day and the rate at which the rumen has to biohydrogenate the fat.

For example, if a diet had 5% fat but only 12 kg DMI per day, the cow would only consume around 840g/day of fat. Slow rumen flow rates at low DMI allow time for the rumen to process this level of fat even if it is all polyunsaturated fatty acids (PUFAs).

However, if a diet had 5% fat but 22 kg DMI per day, the cow consumes around 1100g/day of fat. This is much harder to process, especially as rumen flow rates are much faster.

ADVISER ALERT

Long-chain fatty acids are toxic to fibre-digesting bacteria.

When rumen-digestible fat intake exceeds about 5% of total DM, the digestion of fibre in the rumen may fall, with the level of the response varying with the amount of fat fed and its degree of unsaturation.

Note however that there is insufficient information on digestible fat intake from pasture by grazing cows to make informed decisions about when fats in supplements and the total diet will have measurable effects on fibre digestion.

PROTEIN SUPPLEMENTS

Protein-rich supplements include grain legumes, vegetable protein meals and urea. Animal protein meals have been used in the past, but recent legislation has banned them because of the risk of disease.

Protein levels may vary widely, as can the proportions of RDP and UDP making up crude protein.

Commercial pellets often contain more UDP than do their raw ingredients.

The temperatures used to manufacture commercial feed pellets can affect the protein, protecting it to some extent from breaking down in the rumen.

The degradability of protein — that is, its proportions of RDP and UDP — is often estimated by measuring the solubility of protein in a feed or incubating feed samples in nylon bags in the rumen for various lengths of time.

The degradability of protein in the diet depends on many factors including:

- dry matter intake
- how long feed stays in the rumen
- the degree of processing
- the total protein intake
- the supply of dietary energy to the rumen microbes.

Therefore, the proportions measured in a laboratory test for RDP and UDP may not necessarily be the same as when the feed is eaten by a cow. This is explained in Ch 4.

Categories of degradability of protein have been developed to help assess the UDP supply in feeds. Note that protein supplements rated as good are likely to have undergone considerable processing.

Categories used to assess the ability of feeds to supply UDP		
Category	**Undegradable dietary protein (UDP)**	**Rumen degradable protein (RDP)**
Good	50–69 %	31–50 %
Moderate	30–49 %	51–70 %
Low	10–29 %	71–90 %
Source: Stockdale 1999.		

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The amino acid profile of protein from milk, rumen bacteria and selected feed stuffs - % of crude protein

	Milk	Rumen bacteria	Wheat	Canola	Copra	PKM	DDGS	Brewers grain
Lysine	8.4	8.5	2.7	5.3	2.6	2.8	2.3	3.5
Methionine	2.4	2.4	1.5	2.0	1.3	1.8	1.8	2.0
Cystine	1.0	1.2	2.2	2.4	1.5	1.2	1.8	2.0
Threonine	4.4	5.4	2.8	4.3	2.9	2.9	3.5	3.6
Isoleucine	5.8	5.7	3.3	3.8	3.1	3.3	3.5	4.0
Tryptophan	1.3	1.3	1.2	1.3	0.8	0.8	0.8	1.2
Arginine	3.5	5.2	4.7	5.9	10.6	11.5	3.8	4.9
Valine	6.6	6.0	4.2	5.1	4.9	4.8	4.9	5.4
Phen. Alan.	4.9	4.9	4.4	3.9	4.1	4.0	4.6	5.4
Tyrosine	5.0	4.4	2.9	3.0	–	–	–	3.4

Source: Ian Sawyer Feedworks.

RUMINANT FEED BAN

The feeding of restricted animal material to ruminants is banned throughout Australia.

Restricted animal material is any material taken from a vertebrate animal. It includes rendered products such as blood meal, meat meal, meat and bone meal, fish meal, poultry meal and feather meal, and compounded feeds made from these products.

Grain legumes as a source of protein and energy

Grain legumes are multi-purpose as they are good sources of both protein and energy. Note however that their protein is very degradable in the rumen.

The nutritive value of protein-rich supplement: grain legumes

Protein rich supplement	Crude protein % of DM		UDP supply
	Average	Range	
Lupins	33	28–40	Poor
Peas	24	20–27	Poor

Source: Stockdale 1999.

Vegetable protein meals

Plant-based protein meals generally have only moderate levels of UDP as the amino acids supplied in the protein do not match the requirements of lactating cows as well as the amino acids supplied from animal sources.

An important aspect of protein meals is that their energy levels are comparable to those of cereal grains.

A number of plant-based protein meals also provide reasonable levels of NDF.

The nutritive value of protein-rich supplements: vegetable protein meals

Protein rich supplement	Crude protein % of DM		UDP supply
	Average	Range	
Soybean meal	52	46–59	Medium
Safflower meal	43	22–54	Medium
Cottonseed meal	42	37–45	Medium
Canola meal	39	33–43	Poor
Sunflower meal	35	26–50	Medium
Linseed meal	34	30–40	Medium

Source: Stockdale 1999.

However, as discussed in Ch 4, RDP/UDP values of feeds are not fixed. The faster the rumen flow rates, the lower the ratio of RDP/UDP for a given feed. So in higher-producing cows, with high feed intakes and fast rumen passage rates, canola meal can supply significant amounts of UDP.

Urea

Urea is a common source of nitrogen, but it is not a protein. It has no energy value and is potentially 100% rumen degradable. It is mainly used in very limited amounts as a substitute for true protein sources in feed mixtures and pellets.

Urea is effective only when fed in combination with an energy source such as cereal grains or maize silage.

The nutritive value of urea supplement		
Protein-rich supplement	**Crude protein % of DM**	
	Average	Range
Urea	250*	–
Source: Stockdale 1999.		

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*Urea is very high in nitrogen. When the crude protein factor of 6.25 is applied to the percentage of nitrogen in urea, the result is a very high crude protein percentage.

It is recommended that urea only be fed to cows that have a fully functioning rumen and at a maximum rate of 1% of total DM intake.

Responses to protein supplements

Protein supplements can provide rumen degradable protein (RDP) and undegradable protein (UDP). The price and availability of the different protein meals vary widely during the year.

Canola meal, cottonseed meal and lupins are the most popular protein supplements fed in Victoria. They are relatively cheap, readily available, palatable and a good source of RDP. They also contain significant amounts of UDP, particularly at high total feed intakes, with fast rates of passage through the rumen.

Sources of UDP are generally much more expensive.

The goal is to maximise the production of microbial protein (mop up RDP which can be in excess in pasture systems), then focus on UDP supply, as this is generally more expensive. It is important not to make an 'either – or' choice: both RDP and UDP need focus, depending on the target milk yield.

Responses to rumen-degradable protein (RDP) are seen when there is excess energy relative to protein in the diet.

Responses to undegradable dietary protein (UDP) mainly manifest themselves as increases in feed intake. This may then lead to a milk response.

Increased supply of undegradable dietary protein (UDP) may stimulate mobilisation of body tissue (fat and protein) if nutrient supply from the diet is limiting.

Increased supply of undegradable dietary protein (UDP) to the intestine provides more efficient supply of amino acids for milk synthesis than via microbial protein from rumen. Protein sources (such as canola meal, cottonseed meal and lupins) have limitations in terms of their amino acid profiles, so you need to be careful that all essential amino acids are being supplied by the diet.

If protein is provided in excess of requirements, or insufficient energy is available to utilise the rumen degradable protein, then milk production may be less than expected.

Energy is required to remove the excess protein from the body.

Extra protein is often fed together with energy supplements during the summer and autumn. This is when protein levels are low in both the pasture and in many of the cereal grain and turnip supplements fed at these times of the year. Milk production responses have been recorded to both RDP and UDP supplementation.

A key response often seen with UDP supplements is an increase in intake, which results in extra milk. Therefore, unless cows are given the opportunity to consume more DM, the potential benefit of the use of UDP will not be realised. Positive responses are thus more likely to occur under indoor feeding conditions.

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Appendix 1: Australian results: Immediate marginal milk production

Immediate marginal milk production responses, relative to unsupplemented production, from feeding concentrate supplements to pasture-fed lactating dairy cows in short-term grazing feeding experiments

Region	Amount of supplement kg DM / cow.day	Stage of lactation/ Season	Pasture allowance kg DM /cow.day	Marginal milk responses	
				g FatCM/kg DM supplement	g F+P/kg DM supplement
North Vic[1]	1.8–6.3	Late/Aut.	15, 26	0.6	-
North Vic[2]	4.6	Early/Spr.	30	0.4	-
	4.9	Early/Spr.	30	0.6	-
	4.9	Mid/Summ.	30	1.2	-
	3.0	Mid/Summ.	30	1.2	-
	4.7	Early/Spr.	40	0.5	-
	4.8	Mid/Summ.	40	1.0	-
	4.9	Late/Aut.	40	1.0	-
North Vic[3]	5.0	Mid/Summ.	27	1.3	91
	5.0	Mid/Summ.	27 (high mass)	1.0	75
	5.0	Mid/Summ.	48	0.8	63
	5.0	Mid/Summ.	48 (high mass)	0.8	55
North Vic[4]	3.0	Late/Aut.	25	1.1	76
	5.0	Late/Aut.	25	1.2	82
	7.0	Late/Aut.	25	1.1	74
	9.0	Late/Aut.	25	0.9	68
	10.4	Late/Aut.	25	0.9	49
	3.0	Late/Aut.	31	1.0	85
	4.9	Late/Aut.	31	0.6	42
	5.9	Late/Aut.	31	0.5	38
North Vic[5]	4.3	Early/Spr.	36	0.4	-
North Vic[6]	4.9	Early/Spr.	30	0.6	41
	5.0	Mid/Summ.	30	0.6	45
	4.9	Mid/Summ.	30	1.1	77
	4.7	Early/Spr.	40	0.5	29
	4.8	Mid/Summ.	40	1.1	78
	4.9	Mid/Summ.	40	1.0	69
	5.0	Late/Aut.	30	0.9	80
	4.4	Early/Spr.	30	0.4	50
	4.9	Mid/Summ.	30	0.7	52
	5.0	Mid/Summ.	30	1.3	96
	5.0	Late/Aut.	30	1.3	100
	4.7	Early/Spr.	40	0.7	56
	4.8	Mid/Summ.	40	1.0	84
	4.9	Mid/Summ.	40	0.9	73
	5.0	Late/Aut.	30	1.0	93
South Vic[7]	4.4	Late/Aut.	42	0.6	58
	4.3	Late/Aut.	21	1.1	77
	1.8–6.7	Late/Aut.	26	0.7	61
North NSW[8]	2.7	Mid/Aut.	-	1.2	96
	5.4	Mid/Aut.	-	0.4	35
	2.7	Late/Aut.	-	2.1	170
	5.4	Late/Aut.	-	0.8	65

1 Stockdale and Trigg (1985). *Australian Journal of Experimental Agriculture* **25**, 739–744.; **2** Stockdale (1999) *Australian Journal of Experimental Agriculture* **39**, 379–387.; **3** Wales et al. (1999) *Australian Journal of Experimental Agriculture* **39**, 119–130.; **4** Walker et al. (2001) *Australian Journal of Experimental Agriculture* **41**, 1–11.; **5** Stockdale (2004) *Australian Journal of Experimental Agriculture* **44**, 1–9. **6** Stockdale (2008) *Australian Journal of Experimental Agriculture* **48**, 866–872.; **7** Robaina et al. (1998) *Australian Journal of Experimental Agriculture* **38**, 541–549.; **8** Reeves et al. (1996) *Australian Journal of Experimental Agriculture* **36**, 763–770.

Appendix 2: New Zealand and Ireland results: short term grazing feeding experiments

Immediate marginal milk production responses, relative to unsupplemented production, from feeding concentrate supplements to pasture-fed lactating dairy cows in short-term grazing feeding experiments

Country	Amount of supplement kg DM / cow.day	Stage of lactation/ Season	Pasture allowance kg DM /cow.day	Marginal milk responses	
				g FatCM/kg DM supplement	g F+P/kg DM supplement
NZ[9]	< 2.0	Mid/Spr.	-	0	
NZ[10]	5.0	Early	30	0.4	40
	5.0	Mid	30	0.6	45
	5.0	Late	29	0.5	38
	4.8	Spring	27	0.1	17
	4.9	Summer	36	0.6	47
	5.3	Autumn	31	0.5	43
	5.1	Winter	24	0.7	57
Ireland[11]	4.5	Early	-	0.2	-
	2.7	Mid	-	0.6	-
	3.2	Mid	-	0.6	-
	3.5	Late	-	0.6	-

9 Penno et al. (1996) *Proceedings of the New Zealand Society of Animal Production* **56**, 236–238.; **10** Penno et al. (2006) *Animal Science* **82**, 661–670 and 671–681.; **11** Stakelum et al. (1988) Proceedings of the Moorepark Dairy Farmers Conference, pp. 25–27.

Appendix 3: Indoor feeding experiments: Immediate marginal milk production responses

Immediate marginal milk production responses, relative to unsupplemented production, from feeding concentrate supplements to pasture-fed lactating dairy cows in indoor feeding experiments

Region	Amount of supplement kg DM / cow.day	Stage of lactation	Pasture allowance kg DM /cow.day	Marginal milk responses	
				g FatCM/kg DM supplement	g F+P/kg DM supplement
North Vic[12]	2.7, 5.4, 9.6	Early	HI = 6.6	0.8, 0.7, 0.5	64, 58, 46
	3.6, 6.1	Late	HI = 6.5	0.8, 0.8	66, 69
	3.6, 8.7	Mid	HI = 7.0	0.7, 0.6	57, 50
	2.2, 4.4	Late	HI = 6.7	1.0, 1.0	74, 74
	2.2, 4.5	Early	HI = 6.8	1.9, 1.9	135, 136
North Vic[13]	4.5	Early	HI = 6.8	1.6	118
	4.5	Early	HI = 11.6	0.6	49
	4.5	Early	HI = 9.4	0.8	69
	4.4	Late	HI = 6.7	0.8	66
	4.4	Late	HI = 9.1	0.8	64
	4.4	Late	HI = 11.6	0.5	43
North Vic[14]	2.5–7.0	Mid	HI = 17.7	1.3	90
North Vic[15]	2.5–5.0	Early	HI = 19.0	0.9	66

12 Stockdale et al. (1987) *Australian Journal of Agricultural Research* **38**, 927–940.; **13** Stockdale and Trigg (1989) *Australian Journal of Experimental Agriculture* **29**, 605–611.; **14** Leddin et al. (2009) *Journal of Dairy Science* **92**, 2747–2757; **15** Leddin et al. (2010) *Animal Production Science* **50**, in press.

15 FORMULATING A MILKER DIET

STEPS TO MANUAL DIET FORMULATION

1. **Determine the farmer's goals**
2. **Calculate daily nutrient requirements**
3. **Establish nutrients in available feeds**
4. **Estimate the daily feed intake**
5. **Construct a diet using available feeds to meet energy, protein and fibre requirements**
6. **Add minerals and vitamins as required**

Formulating a diet means getting the right balance between supply and requirements to enable animals to be healthy and productive. A number of key factors need to be integrated:

- the farmer's goals
- the cows' nutrient requirements
- the feeds available (feed intake potential and their nutritive characteristics)
- the relative cost per unit of available feeds.

Herd production, fertility, body condition and health are all good indicators of the success or otherwise of nutritional strategies.

You may need to try several combinations of forages and concentrates to achieve a balanced diet within the limits of the cows' appetites.

Farmer's goals

Any conversation about formulating milker diets must start with the farmer's cow performance goals. Consider the following:

- milk production – litres, fat/protein
- body condition targets
- fertility – approach to transition and calving pattern.

Although energy, protein and fibre are the key nutrients of concern, minerals and vitamins should not be ignored.

Cow daily nutrient requirements

Cow nutrient requirements should be calculated using realistic production goals. Factors to consider are:

- growth
- animal activity
- stage of pregnancy
- changes in body condition
- milk production and composition.

Minerals and vitamins are necessary to fine tune the system depending on what feeds are included in the diet. Trace element deficiencies are often regional and seasonal, with some of the variability depending on pasture management.

Feeds should be analysed for their nutritive characteristics at a reputable feed-testing laboratory.

Search for a list of feed labs on Dairy Australia's website *Dairy Australia: List of Feed Labs.*

ESTABLISH NUTRIENTS IN AVAILABLE FEEDS

Feeds can vary markedly in their nutritive characteristics. Obtaining a feed-test analysis is the best way to establish the nutritive characteristics of a feed.

While not ideal, best guesses can be made by using the pasture and supplement databases found on the DELWP website. These can be sufficiently accurate for many feeds when undertaking a basic diet formulation, however this website does not provide information about mineral or vitamin concentrations.

Typical feed-testing laboratory analyses of the nutritive characteristics of some common feeds used on dairy farms	
Sample 1 **Reference: short feed. Sample details: pasture**	
Moisture	82.6%
Dry matter	17.4%
Crude protein	25.8% of dry matter
Neutral detergent fibre	28.4% of dry matter
Digestibility	77.8% digestible dry matter
Estimated metabolisable energy (ME)	11.2 MJ/kg dry matter
Sample 2 **Reference: rank feed. Sample details: pasture**	
Moisture	75.4%
Dry matter	24.6%
Crude protein	12.0% of dry matter
Neutral detergent fibre	56.1% of dry matter
Digestibility	59.0% digestible dry matter
Estimated metabolisable energy (ME)	8.0 MJ/kg dry matter
Sample 3 **Reference: grain. Sample details: wheat**	
Moisture	10.2%
Dry matter	89.8%
Crude protein	12.6% of dry matter
Neutral detergent fibre	5.0% of dry matter
Digestibility	86.4% digestible dry matter
Estimated metabolisable energy (ME)	12.8 MJ/kg dry matter
Source: DELWP.	

ESTIMATE DAILY FEED INTAKE

As well as knowing what the cow needs and what nutrients the feeds can provide, an estimate of the amount of feed that is needed to provide those nutrients is necessary.

In some instances, farmers should know how much is being fed, for example concentrates in the dairy and, if a partial or total mixed ration is being fed, feed-out wagons generally have load cells attached to them.

The problem is that it is difficult to measure the pasture intake of grazing animals accurately. This information is critical when formulating a balanced diet.

See Ch 12 Feeding cows pasture.

Pasture intake can be estimated from automated measurements of pre- and post-grazing pasture mass. Options for assessing pasture intake include:

- gumboot before and after measures
- a plate meter
- a scanner on a trailer on the back of a quad bike.

Alternatively, if the quantities and energy values of all feeds other than pasture are known, a back calculation from milk production can be used to estimate pasture intake.

COSTS OF FEEDS

Decisions on what supplements to feed depend on more than just the cost of the feed itself.

Assessing the price of an individual feed depends on whether that feed is expected to provide energy, protein or fibre. If energy is deficient for example, a feed that provides the most energy at the cheapest price per MJ is required.

Storage losses, wastage, increased capital requirements, extra labour and other costs need to be considered when deciding on the supplement to best balance a diet.

Feeding brewers grain requires storage facilities, a front-end loader and maybe a feed-out cart, and a feed trough or feed pad.

Lupins are popular as a source of protein during summer and autumn, but their protein is very degradable and their hard seed coat places extra wear on grain mills.

Bail-feeding limits the choice of supplement to cereal grains, meals/mixes and commercial pellets. Commercial pellets and grain mixes are often selected because they are usually more consistent in quality than cereal grains and do not require any processing.

Once a farmer has invested in equipment to handle byproducts, the range of supplements that can be fed expands considerably.

APPLIED NUTRITION MODEL STUDY

The main outcomes from the 2009 Dairy Australia study were detailed descriptions of the models that best predicted the observed milk yield performance in several experimental datasets.

For a report on how the models work, and the concepts used to model rumen function and predict energy and protein requirements, feed intake, milk response, live weight changes and pasture substitution, search for *Dairy Australia Review of 11 Applied Dairy Nutrition Models.*

COMPUTER MODELS FOR DIET FORMULATION

In 2009, Dairy Australia commissioned SBScibus to review and evaluate eleven applied dairy nutrition models commonly used in Australia at the time. The summary report produced provides technical details for each of the tactical and strategic nutrition models reviewed including:

- key concepts used to model rumen function, and predict energy and protein requirements, feed intake, milk response and liveweight changes, pasture substitution
- information required to perform a simulation
- other aspects of the simulation process used.

It also provides additional details on each model's development and objectives.

Each model reviewed has a number of strengths and limitations, and is suitable for users with different levels of knowledge, skill and experience.

Although there were major differences between models in terms of what they were designed to do, and in the information underpinning each of them, almost all the models closely predicted the actual milk production using some independent datasets. This should give users of the models confidence when using them.

CAUTION

The models each use different energy and protein systems depending on their origin (the UK, US and Australia) and differ in their level of sophistication. For example, CPM Dairy uses the CNCPS protein fractions, whilst Feed into Milk uses metabolisable protein. DietCheck simply uses crude protein.

Nutrition models are decision support tools: they rely on the common sense and skills of the user.

AMINOCOW

AminoCow was developed by the DeGussa Company with input from Drs Ed Byers and Mike Hutjens. The program is a tool to investigate production limitations. A least-cost formulation or profit-maximising function is not provided and the program does not predict milk production. Rather, the outcomes provided are similar to those of RationCheck, expressed in terms of the capacity for the test diet to meet requirements for a given milk production.

The program provides a flexible approach to the calculation of requirements, as the user can opt to use the NRC (1989) energy system or the net energy system provided by the model. The focus of AminoCow is on amino acid requirements, especially methionine and lysine.

The model uses a factorial approach in setting amino acid requirements. For milking cows, the factors involved are maintenance, milk production, body growth and body condition repletion. Body growth is calculated if the animal is both less than 48 months of age and less than ideal body size. Body condition repletion is calculated from a desired body condition score of 3.5 at dry off (1–5 scale). Requirements for protein are based on NRC (1989) and do not allow for the effect of rumen outflow rates on degradation of protein.

CAMDAIRY

The core program of the CamDairy model is a bio-mathematical model that incorporates functions to predict nutrient requirements, feed intake, substitution effects when feeding concentrates, tissue metabolism and partition of nutrients between milk production and growth.

It incorporates an econometric model ('Maximum Profit') that uses linear programming procedures to formulate diets that maximise income above feed costs, while meeting nutrient requirements and satisfying constraints on feed supply and milk production requirements.

Other programs in the CamDairy package are 'Least Cost', a program that calculates a least-cost diet and 'Analysis', a program that predicts likely milk production given the characteristics of the cows, feed intake and feed composition

CPM DAIRY

CPM Dairy is a US model, and is an extension of the Cornell Net Carbohydrate and Protein System (CNCPS).

It was developed with the aim of providing an applied platform for nutritional decision-making. The CNCPS in CPM Dairy differs from traditional programs by accounting for dynamic attributes of feed ingredients (such as passage and digestion rates). By using these attributes, rumen function is modelled in a manner that allows for a better estimation of rumen microbial yields.

Although the diet optimisation function is more suited to total mixed rations than to pasture-based feeding systems, it can be used effectively but requires expert hands. However, some areas of the program need upgrading, particularly those associated with rumen pH and digesta flow rates.

DIET CHECK

This northern Victorian program estimates the requirement of grazing lactating cows for ME using SCA (1990) and estimates herbage intake in strip grazing or small paddock rotation systems, whist modelling substitution effects.

A key limitation to Diet Check is that it should only be used where grazed pasture constitutes more than 50% of the diet. Otherwise, it is simple and easy to use, and is an excellent learning and tactical decision support tool.

FEED INTO MILK (FIM)

A UK model developed in the first instance as an on-farm application for advisers and service providers to provide feed formulations, it uses ATP yield as the energetic basis for rumen function.

There are three decision support systems in the model, to predict the likely effect of a given diet on milk yield and components, predict the supply and adequacy of amino acids, and provide a focus on rumen stability.

It is not well-suited to farmer user.

GRAZFEED

Grazfeed is a component of the GRAZPLAN decision support project developed by CSIRO.

It predicts the intake of energy and protein and their use for maintenance and production according to SCA (1990), with some recent modifications as reported in CSIRO (2007).

GrazFeed takes into account the type of animal, the availability and quality of pasture, selective grazing and interaction with supplementary feeds (for example, substitution).

Its stated objective is to help farmers decide what level of animal production a particular pasture will support and how much of a specified supplement would be needed to meet a target production level. It helps a farmer to formulate a way of achieving this aim that realistically simulates the interactions between selective grazing and substitution on feed intake by grazing animals.

RATIONCHECK

RationCheck is a simple tactical program developed in NSW. It is somewhat similar to Diet Check in its assessment of nutrient sufficiency of a diet although it is generally based on US recommendations rather than Australian ones.

It can assess the nutrient balance of diets fed to dry cows and replacement heifers. It can also calculate average milk production and the margin-over-feed from the input supplied.

RUMEN8

Rumen8 was developed in Western Australia as a tool for farmers and nutritionists to explore diets and make adjustments according to production and estimates of pasture utilisation and consumption.

It estimates requirements for feed intake and ME and metabolisable protein. The program is based on AFRC (1993) equations, except for DM intake which is estimated using NRC (2001) equations.

Rumen8 has the ability to provide a least-cost diet and can calculate margin-over-feed cost.

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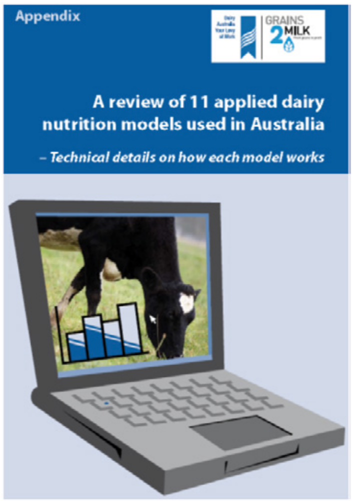
Key resource

Summary Report: A review of 11 applied dairy nutrition models used in Australia (2009) Dairy Australia, search for *Dairy Australia Review of 11 Applied Dairy Nutrition Models.*



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COW REQUIREMENTS FOR ENERGY

The energy in feed is a measure of that feed's ability to help the cow function and be productive. There are two measures of energy in common use: digestibility and metabolisable energy.

All feeds have a gross energy value. Some of the gross energy is lost in the faeces. The energy that is absorbed by the cow is termed digestible energy.

Some of the energy released by digestion is not used by the cow. It is belched out as methane and carbon dioxide, passed out in the urine and lost as heat created during rumen fermentation.

All the remaining energy is known as metabolisable energy (ME).

Net energy

Efficiency factors are applied to ME to calculate net energy, which is the energy actually used by the cow. Invariably, when calculating energy requirements, the calculation starts with the net energy needed for a process or product, and the appropriate efficiency factor is applied to the net energy to arrive at the amount of ME that has to be provided.

By multiplying the amount of ME for a process by the appropriate efficiency factor, it is possible to calculate how much of the ME is actually used by the cow for that process. This is commonly referred to as net energy.

!

CAUTION: ME ANALYSIS OF PASTURES

An anomaly that has come to light with the measurement of digestibility of pasture, and its conversion to ME, is that it is highly unlikely that the ME of grazed pasture can exceed 12.5 MJ/kg DM in spite of what the calculation from digestibility might suggest.

Since pasture typically has 10–12% of its DM as indigestible material (commonly referred to as ash), this effectively caps its ME at 12.5 MJ. In contrast, cereal herbages can be higher than this because they have less ash, and concentrates that contain fats and oils can have energy densities that are significantly higher because the energy density of fat/oil is up to three times greater than that of carbohydrates.

Efficiency factor	
k_m	efficiency of use of ME for maintenance
k_c	efficiency of use of ME for pregnancy
k_l	efficiency of use of ME for milk production
k_g	efficiency of use of ME for tissue change

The metabolisable energy requirements for maintenance, growth or condition change, pregnancy and lactation are calculated from the net energy (the energy actually used by the cow) needed for a particular process while taking into account the efficiency of use of ME for that purpose.

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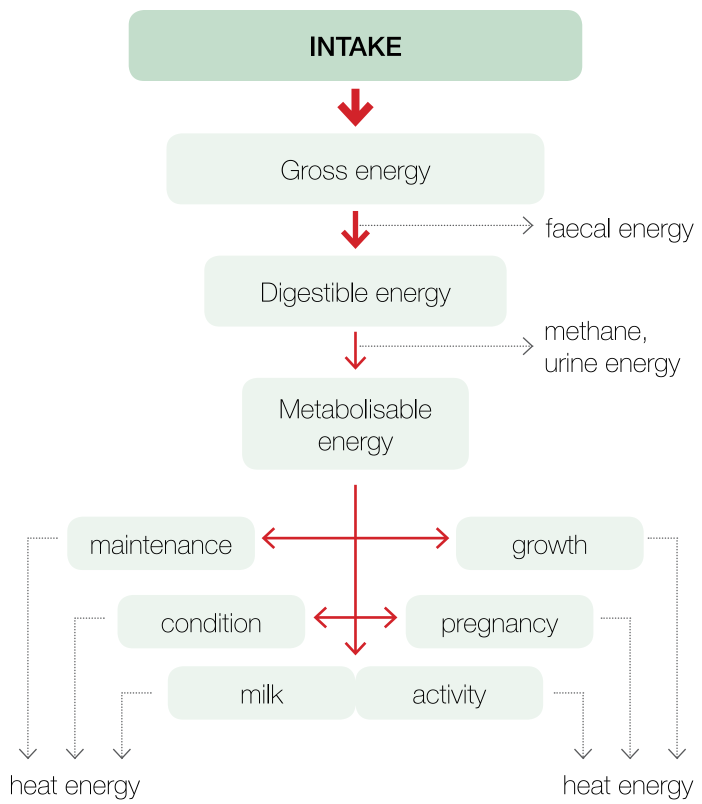

Source: Adapted from Chamberlain & Wilkinson 1998.

DIGESTIBILITY

Digestibility relates to the portion of food which is not excreted in the faeces: that is, what is digested and potentially available for the cow to use for bodily functions.

Just as the dry matter of feeds is measured so they can be compared on an equal footing, so too is the digestibility of feeds using a consistent protocol for comparative purposes.

Digestibility is not a direct measure of energy, but it does indicate overall feed quality. The higher the digestibility of a food, the higher will be its metabolisable energy.

The most common unit of digestibility is percentage. A pasture with a dry matter digestibility (DMD) of 50%, for example, means that only half of the feed eaten will actually be of use to the animal. The other half will be excreted in the faeces.

The main measure of energy used is metabolisable energy, the energy remaining after gas, heat and faecal and urinary energy have been accounted for.

METABOLISABLE ENERGY

Metabolisable energy is the energy available for use by the cow. It is the energy used for:

- maintenance of body systems
- activity
- milk production
- pregnancy
- weight gain.

It is important to remember that energy is not metabolised or used by the cow with the same efficiency for all processes.

ADVISER ALERT: INFORMATION YOU NEED BEFORE YOU CAN CALCULATE COW REQUIREMENTS

- Bodyweight
- Age
- Stage of lactation
- Pregnancy status and duration
- Current production – litres, % fat, % protein
- Estimate of current changes in body condition score
- Current diet – grazing/non grazing, estimate of diet quality

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Calculating metabolisable energy content of a feed

The ME or the energy density of feeds can be measured by housing cows in respiration chambers or by bomb calorimetry but it is most commonly calculated from its dry matter digestibility (DMD).

The calculation recommended by CSIRO (2007) are:

Calculation for...	Calculation
Pasture and hay	ME = 0.17 x DMD – 2.0
Silage	ME = 0.172 x DMD – 1.707
Energy & protein concentrates	ME = 0.134 x DMD + 0.235 x EE

The term **EE** refers to **ether extract**, which is an indirect measure of fat in a feed.

For cereal grains,
EE if often around 2%.

Note that the calculation of the ME of silages can be more complicated than for the other feed groups.

Although CSIRO (2007) provide an equation for doing this, the *Successful Silage* manual covers some of the pitfalls of doing this in detail. Search for *Successful Silage NSW Department of Primary Industries* and see p. 325.

Megajoules of metabolisable energy

Energy requirements and the energy density of feeds is referred to in terms of megajoules of metabolisable energy per kilogram of dry matter (MJ ME/kg DM).

If a feed contains 12 MJ/kg DM, then each kg of DM of that feed contains 12 MJ of ME available for use by the cow. A feed with 13 MJ/kg DM has a higher energy content than, say, a feed with 10 MJ/kg DM.

See chapters 13 and 14 for ME densities of a range of feeds pasture, forage supplements and concentrate supplements.

Calculations are based on research from feeding trials, comparative slaughter methods and/or calorimetry experiments.

Metabolisable energy requirements are divided into five categories:

- energy for maintenance (to maintain body temperature and vital body processes and for physical activities including those associated with feeding)
- energy for activity (walking between from dairy/paddock/ feed pad)
- energy for maintaining a pregnancy
- energy for milk production
- energy for growth/condition change.

These requirements are calculated individually and added to determine total daily requirements.

The energy requirements detailed here are a summary of the information contained in CSIRO (2007) Nutrient Requirements of Domesticated Ruminants. Eds M Freer, H Dove and JV Nolan: CSIRO Publishing: Collingwood, Victoria.

This document provides information specific to an Australian grazing environment and updates its predecessor SCA (1990).

ENERGY REQUIRED FOR MAINTENANCE

Maintenance requirements of dairy cattle depend on their size and age and the quality of their diet and whether they are dry or lactating.

Metabolisable energy requirements for maintenance increase with both live weight and milk production. In addition, grazing incurs an additional energy cost compared with housed animals. This is calculated by adding 10% to maintenance requirements.

Energy is used for maintaining a cow's metabolism. This includes breathing and maintaining body temperature. Physical activity such as walking and eating add to the maintenance requirement, as do climatic conditions and physiological state (for example lactation).

The equation in the table below is used to calculate ME requirements for the maintenance (ME_m) of dairy cows and is taken directly from CSIRO (2007).

ME_m

Metabolisable energy requirements for maintenance; varies with the level of milk production

ME_p

Amount of dietary ME (MJ) used directly for production

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Equation 1 Metabolisable energy requirements for the maintenance (ME_m) of dairy cows	
ME_m (MJ/day) = K.S.M.(0.28W^{0.75}.exp(-0.03A))/k_m + 0.1ME_p$	
K	= 1.4 for *Bos taurus* animals
S	= 1.0 for females and 1.15 for bulls
M	= 1 + (0.23 x proportion of digestible energy from milk)
W	= live weight (kg)
A	= age in years, with a maximum value of 6.0
k_m	= net efficiency of use of ME for maintenance k_m = (0.02 x average ME of diet) + 0.5 Varies with the ME concentration of the diet
ME_p	ME_p = amount of dietary ME (MJ) being used directly for production

See look-up tables 1 a-e (p16.17–18); also see 'Energy required for maintenance – worked example' (p16.29)

E_{graze}

The energy associated with grazing is included either as 10% of ME_m for grazing cows or zero for housed cows.

E_{graze} as calculated by 10% of ME_m differs from the calculation method described in CSIRO 2007.

It closely matches numbers calculated for rotational grazing systems as seen in Australian dairy herds and is much simpler to calculate.

Activity – walking to and from the dairy

ME_m already allows for the expenditure of energy on the physical activities that are considered normal including standing, eating and ruminating. E_{graze} accounts for energy for walking, eating and ruminating during grazing.

In addition, energy is used by dairy cows when walking to and from the dairy each day. The horizontal and vertical components of the activity allowance are calculated in the following equations.

Equation 2 Energy used when walking to and from the dairy each day

Horizontal activity (HA) = $(0.0026 \times \text{distance} \times W)/k_m$
Vertical activity (VA) = $(0.028 \times (\text{distance} \times \text{vert.}) \times W)/k_m$

W	= Live weight Horizontal and vertical components based on live weight (W)
HA	= the energy cost associated with horizontal activity
VA	= the energy cost associated with vertical activity
Walking (horizontal component)	= 2.6 kJ/kilometre per kg W
Walking (vertical component)	= 28 kJ/kilometre per kg W
Distance	= the distance (kilometres) walked per day when away from the paddock
vert.	accounts for variation in the gradation of terrain and is defined by the kilometre vertical climb per kilometre walked (flat: 0.001; undulating: 0.04; steep: 0.1)
k_m	= the efficiency of use of ME for maintenance

See look-up table 2 (p16.20); also see 'Worked example – Activity – walking to and from the dairy' (p16.30)

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K_C

Equals the efficiency of use of ME for conceptus energy gain (k_c = 0.133)

ENERGY REQUIRED FOR PREGNANCY

The ME associated with pregnancy is minimal until the last trimester, when it increases exponentially through to term.

A cow's ME requirement for pregnancy allows for growth of the uterus as well as the foetus.

Although looking complicated, the calculation of $ME_{pregnancy}$ as found in CSIRO (2007) can be easily accomplished in Excel.

Equation 3 Metabolisable energy requirement for pregnancy $ME_{pregnancy}$	
$ME_{pregnancy}$ = 349.16*0.0000576*EXP(-0.0000576*t)*SBW*EXP(349.22-349.16*EXP(-0.0000576*t))/k_c	
SBW	= scaled birth weight, which is the ratio of expected birth weight of the foetus to a standard 40 kg Holstein-Friesian calf
t	= time (days) after conception
k_c	= the efficiency of use of ME for conceptus energy gain (k_c = 0.133)
See look-up table 3 (p16.22); also see 'Worked example – Energy required for pregnancy' (p16.31)	

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ME_{milk}

Metabolisable energy required per litre of milk

K_l

The net efficiency of use of ME for milk production by cows

k_l varies directly with ME concentration in the diet

ENERGY REQUIREMENTS FOR MILK PRODUCTION

The ME needed to produce a litre of milk increases as the fat and protein in the milk increase. It is more efficient to convert feed energy to milk protein than to milk fat.

Energy is usually the most important feed component needed to produce milk.

The energy requirement depends on the composition of the milk across a range of fat and protein levels.

The equation to predict the ME/L milk (ME_{milk}), as reported in CSIRO (2007) is expressed in the following equation.

Equation 4 Metabolisable energy used milk production – ME_{milk}

$$ME_{milk} = (0.381 \times F + 0.245 \times P + 0.165 \times L)/k_l$$

F	= milk fat (%)
P	= milk protein (%)
L	= milk lactose (%)
k_l	= 0.02 x ME concentration of the diet + 0.4. The net efficiency of use of ME for milk production by cows (k_l) varies directly with the ME concentration in the diet.

In practice, milk lactose concentration is often not readily available, therefore, by assuming an average lactose concentration of 4.9% this equation becomes $ME_{milk} = (0.381 \times F + 0.245 \times P + 0.8085)/k_l$.

See look-up table 4 (p16.23); also see 'Worked example – Energy requirements for milk production' (p16.32)

In this equation, it is assumed that litres and kilograms of milk are equivalent, which they are not. However, the small difference between the two is not considered worth worrying about.

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ENERGY REQUIREMENTS FOR BODY CONDITION

It takes more energy to put on a body condition score when cows are dry than when they are lactating because energy is used less efficiently during the dry period.

Changes in body tissue mobilisation and deposits are best measured using body condition scoring. Changes in BCS over time can be used to calculate changes in tissue energy.

When an adult cow puts on weight, it is put on mostly as fat. Some of this fat is seen on the backbone, ribs, hips, and on pin bones around the head of the tail. This extra fat is referred to as body condition and can be scored by visual appraisal using the eight-point scale developed by David Earle in the 1970s. A very skinny cow might be scored at 3 and a fat cow might be scored at 6.

Using this eight-point condition score scale, CSIRO (2007) calculate live weight change per unit body condition score as 0.09 x standard reference weight (SRW).

The standard reference weight is approximately the live weight that would be achieved in cows when their skeletal development is complete and their body condition score is in the middle of the range: that is at a body condition score of about 5.

Using the standard reference weight calculation, the table below shows how much a body condition score weighs in different-sized cows.

The weight of one condition score in cows of different sizes

A cow's standard reference weight (kg)	Weight in one condition score (kg)
400 (Jersey)	36
475 (Friesian x Jersey)	43
550 (Friesian)	50
650 (Holstein)	59

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Bigger cows need more ME to achieve a change in body condition score, and this increases as body condition score increases.

When energy is mobilised from tissue, considerably less energy is retrieved to support milk production than it took to deposit the tissue in the first place. This means it is more efficient for dietary energy to be channelled directly into milk than to go via body tissue to milk.

ENERGY REQUIREMENTS DURING GROWTH AND FATTENING – CONDITION GAIN

A number of steps are required to calculate the energy needed to gain condition.

Equation 5 Calculating energy required for empty body gain

EBG = 0.92 x kg live weight per BCS.

BCS	= body condition score

The energy in each kg of empty body gain increases as body condition score increases according to the following.

- Net energy (MJ/kg EBG) = 21.4 + 1.24 x BCS.
- The efficiency of ME use is then divided into the net energy thus obtained to arrive at the amount of ME needed for 1 kg of live weight gain (or 1 body condition score, after multiplying by kg of live weight/ body condition score).
- Even though the efficiencies of ME use for protein and fat are quite different, according to CSIRO (2007) there is no useful alternative other than to use the single term, kg, to describe the efficiency of use of ME for body change. However, this varies depending on whether the cows are dry or lactating.
- In lactating cows, the efficiency of use of ME for energy deposition as tissue (k_g) = 0.60 in all situations, whereas k_g in dry cows varies directly with the ME concentration of the diet, and is calculated from the equation k_g = 0.043 x ME of the diet.
- The latter is the same efficiency as that used for growing animals.

See look-up table 5 a–c (p16.25–16.27); also see 'Calculating ME required for condition gain, Calculating requirements for condition gain and Calculating requirements for condition gain – worked for example cow' (p16.33–16.34)

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K_g

Energy required to convert body tissue for milk production

ENERGY MOBILISATION FROM TISSUE – CONDITION LOSS

The quantity of dietary ME equivalent to the energy mobilised from body tissues for milk production can be estimated as follows.

Equation 6 Calculating net energy (MJ/kg EBG)

For a lactating cow in BCS = 6 that is mobilising body condition, the net energy in each kilogram of empty body weight (EBG; live weight x 0.92) is 29 MJ, which is obtained by solving:
Net energy (MJ/kg EBG) = 21.4 + 1.24 x BCS

BCS	= body condition score
EBG	= empty body gain
k_l and k_g	= 0.60

This energy would be available for milk production. During lactation, kl and kg = 0.60, and the efficiency of conversion of body net energy to milk net energy is 0.84.

Thus, net energy from 1 kg loss in weight used for milk production = 29 x 0.84 = 24.4 MJ of milk net energy, and ME = 24.4/0.60 = 41 MJ.

If the ME required for milk is 5 MJ/L, then about 8 L of milk would come from 1 kg of mobilised live weight.

See look-up table 5 a–c (p16.25–16.27); also see 'Calculating ME required for condition gain, Calculating requirements for condition gain and Calculating requirements for condition gain – worked for example cow' (p16.33–16.34)

The same exercise for a cow in BCS = 4 shows that the ME for milk from 1 kg of mobilised tissue is 37 MJ, or about 7 L of milk.

Importantly, considerably less energy is retrieved from mobilised tissue to support milk production than it took to deposit the tissue in the first place.

Therefore, it is much more efficient for dietary energy to be channelled directly into milk than to go via body tissue to milk.

If you plan to utilise the formulae directly for calculating cow requirements (either manually or by building a spreadsheet), it is recommended that you consult the source reference (CSIRO 2007) directly.

The foregoing refers to a **kilogram** of mobilised tissue. The process for estimating the ME associated with tissue mobilisation in lactating dairy cows based on a **change in condition score** is summarised below.

The process for estimating the ME requirements for tissue mobilisation in lactating dairy cows using changes in condition score where △ represents change over time and NE is net energy

Process for calculations	CSIRO (2007)
Kg of tissue mobilised	= CS△ x (SRW x 0.09)
Kg empty body gain (EBG)	= 0.92 x kg of tissue
MJ/kg EBG	= 21.4 + 1.24 x average CS
NE in △	= kg EBG x MJ/kg EBG
ME for milk production	= (NE in △ x 0.84)/k_l

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EFFECT OF CLIMATIC STRESS ON ENERGY REQUIREMENTS

The cow's comfort zone (thermoneutral zone) is between 5 °C and 25 °C ambient temperature. As ambient temperatures rise about 25 °C, the cow needs to start actively regulating its body temperature to keep it in the optimal range (38.6–39.3 °C). The cow loses heat to the external environment through evaporative cooling (panting and sweating).

When animals suffer from heat stress to the point that there is rapid shallow breathing, their maintenance energy requirement may have increased by up to 10% whereas when there is deep, open-mouthed panting, the increase might be up to 30%.

In addition to this:

- the cow's feed intake drops by 10–20% short term or long term depending on the length and duration of heat stress
- rumination and cud chewing is decreased
- the cow's ability to digest and absorb nutrients in feed is decreased.

The results of these effects on cows may be:

- milk production drops by 10-25% or more
- reductions in milk protein and fat concentrations
- reduced reproductive performance
- increased cow health problems.

With a trend towards higher temperatures associated with climate change (including higher minimum night temperatures) and an increased frequency of hot spells and heat waves, heat stress is emerging as an issue in all dairying regions of mainland Australia. Some allowance for increased maintenance energy associated with heat stress may need to be considered.

Cold stress is unlikely to directly influence the energy requirements of milking cows in the major dairy areas in Australia. However, cold wet conditions can influence grazing behaviour, which could reduce intakes of grazed pasture.

For further information search Dairy Australia Cool cows.

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ME REQUIREMENTS FOR MAINTENANCE (ME_m)

The following tables provide details on ME requirements for maintenance for:

- cows of different live weight (400–700 kg)
- cows producing daily milk yield (0–40 L/cow)
- cows consuming diets with differing ME concentrations (8, 10 and 12 MJ/kg DM).

Typical ranges of live weight are 350–450 kg for Jerseys, while Friesians are 500-600 kg.

Holsteins of US origin tend to be 600 kg and above.

Two key assumptions are that the average age of a herd is four years and the average energy concentration of milk when calculating the ME_p contribution is 5 MJ/L milk.

The lowest dietary energy (8 MJ/kg DM) is not used for milking cows because anything with this energy level should only be considered as a maintenance feed for dry cows.

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The energy associated with grazing (E_{graze}) is included either as 10% of ME_m for grazing cows or zero for housed cows.

E_{graze} accounts for energy for walking, eating and ruminating during grazing. For animals given feed in stalls, pens or yards, ME_m already allows for the expenditure of energy on the physical activities that are normal in these conditions (including standing, eating and ruminating).

The E_{graze} value for grazing animals is different to that used in CSIRO (2007), but is a locally derived figure that is used in the DELWP pasture intake calculator and Diet Check. However, this energy cost associated with strip-grazing is in agreement with best-grazing conditions as reported by CSIRO (2007).

In the last month of gestation, some energy is also needed for udder regeneration in the lead-up to calving. Since there seems to be a lack of reliable data on this requirement, it has been ignored here, but it is acknowledged that this requirement exists.

See Equation 1 on page 16.29.

Look-up Table 1a: Maintenance of dry cows, and includes E_{graze}			
Live weight (kg)	Diet ME (MJ/kg DM)	Grazing cows	Housed cows
400	8	52	47
400	10	49	44
400	12	46	42
450	8	57	51
450	10	53	49
450	12	50	46
500	8	61	56
500	10	58	53
500	12	55	50
550	8	66	60
550	10	62	56
550	12	59	53
600	8	70	64
600	10	66	60
600	12	63	57
700	8	79	70
700	10	74	68
700	12	70	64

Look-up Table 1b: Maintenance where daily milk yield is 10 L/cow, and includes E_{graze}			
Live weight (kg)	Diet ME (MJ/kg DM)	Grazing cows	Housed cows
400	10	54	49
400	12	52	47
450	10	59	54
450	12	56	51
500	10	63	58
500	12	60	55
550	10	68	61
550	12	64	58
600	10	72	65
600	12	68	62
700	10	80	73
700	12	76	69

Look-up Table 1c: Maintenance where daily milk yield is 20 L/cow, and includes E_{graze}

Live weight (kg)	Diet ME (MJ/kg DM)	Grazing cows	Housed cows
400	10	60	54
400	12	57	52
450	10	64	59
450	12	61	56
500	10	69	63
500	12	66	60
550	10	73	66
550	12	70	63
600	10	77	70
600	12	74	67
700	10	85	78
700	12	81	74

Look-up Table 1d: Maintenance where daily milk yield is 30 L/cow, and includes E_{graze}

Live weight (kg)	Diet ME (MJ/kg DM)	Grazing cows	Housed cows
400	10	65	59
400	12	63	57
450	10	70	64
450	12	67	61
500	10	74	68
500	12	71	65
550	10	79	71
550	12	75	68
600	10	83	75
600	12	79	72
700	10	91	83
700	12	87	79

Look-up Table 1e: Maintenance where daily milk yield is 40 L/cow, and includes E_{graze}

Live weight (kg)	Diet ME (MJ/kg DM)	Grazing cows	Housed cows
400	10	71	64
400	12	68	62
450	10	75	69
450	12	72	66
500	10	80	73
500	12	77	70
550	10	84	76
550	12	81	73
600	10	88	80
600	12	85	77
700	10	96	88
700	12	92	84

ENERGY FOR MAINTENANCE

Maintenance requirements of **lactating** cows per diet quality and feeding system, including E_{graze}

Diet quality **10 MJ**								
Live weight (kg)	Grazing cows Level of production				Non-grazing cows Level of production			
	10 L	20 L	30 L	40 L	10 L	20 L	30 L	40 L
400	54	60	65	71	49	54	59	64
450	59	64	70	75	54	59	64	69
500	63	69	74	80	58	63	68	73
550	68	73	79	84	61	66	71	76
600	72	77	83	88	65	70	75	80
700	80	85	91	96	73	78	83	88

Diet quality **11 MJ**								
Live weight (kg)	Grazing cows Level of production				Non-grazing cows Level of production			
	10 L	20 L	30 L	40 L	10 L	20 L	30 L	40 L
400	53	58	64	69	48	53	58	63
450	57	63	68	74	52	57	62	67
500	62	67	73	78	56	61	66	71
550	66	71	77	82	60	65	70	75
600	70	76	80	86	64	69	73	78
700	78	84	89	95	71	76	81	86

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Diet quality **12 MJ**								
Live weight (kg)	Grazing cows Level of production				Non-grazing cows Level of production			
	10 L	20 L	30 L	40 L	10 L	20 L	30 L	40 L
400	52	57	63	68	47	52	57	62
450	56	61	67	72	51	56	61	66
500	60	66	71	77	55	60	65	70
550	64	70	75	81	58	63	68	73
600	68	74	79	85	62	67	72	77
700	76	81	87	92	69	74	79	84

Maintenance of **dry** cows, at different diet qualities, including E_{graze}						
Live weight (kg)	Grazing cows			Non-grazing		
	8 MJ	10 MJ	12 MJ	8 MJ	10 MJ	12 MJ
400	52	49	46	47	44	42
450	57	53	50	51	49	46
500	61	58	55	56	53	50
550	66	62	59	60	56	53
600	70	66	63	64	60	57
700	79	74	70	70	68	64

ENERGY REQUIREMENTS FOR ACTIVITY – WALKING TO AND FROM DAIRY

This table provide details on the energy needed for walking to and from the dairy for cows of various sizes consuming feed with 10 or 12 MJ ME/kg DM.

Look-up Table 2: The energy needed for walking to and from the dairy each day, on a per kilometre basis

Live weight (kg)	Diet ME (MJ/kg DM)	Gradation of terrain		
		Flat	Undulating	Steep
400	10	1.5	2.1	3.1
400	12	1.4	2.0	2.9
500	10	1.9	2.7	3.9
500	12	1.8	2.5	3.6
600	10	2.3	3.2	4.6
600	12	2.1	3.0	4.4
700	10	2.6	3.7	5.4
700	12	2.5	3.5	5.1

See Equation 2 on page 16.30.

ENERGY FOR ACTIVITY

The energy needed for walking to and from the dairy each day, on a per kilometre basis.

Diet quality 10 MJ			
Live weight (kg)	Gradation of terrain		
	Flat	Undulating	Steep
400	1.5	2.1	3.1
450	1.7	2.4	3.5
500	1.9	2.7	3.9
550	2.1	2.9	4.2
600	2.3	3.2	4.6
700	2.6	3.7	5.4

Diet quality 11 MJ			
Live weight (kg)	Gradation of terrain		
	Flat	Undulating	Steep
400	1.5	2.1	3
450	1.6	2.3	3.4
500	1.8	2.6	3.8
550	2	2.8	4.1
600	2.2	3.1	4.5
700	2.6	3.6	5.3

Diet quality 12 MJ			
Live weight (kg)	Gradation of terrain		
	Flat	Undulating	Steep
400	1.4	2	2.9
450	1.6	2.3	3.3
500	1.8	2.5	3.6
550	2	2.8	4
600	2.1	3	4.4
700	2.5	3.5	5.1

ENERGY REQUIREMENTS FOR PREGNANCY ($ME_{pregnancy}$)

These tables provide details on ME requirements for pregnancy.

Predictions are based on a 281-day gestation period and a calf weight at birth of 40 kg.

For calves of other weights, calculate on a pro rata basis: for example, the SBW of a 30 kg Jersey calf would be 0.75.

As can be seen in the table below, energy requirements for pregnancy only become significant in the last 3–4 months.

Look-up Table 3: Average daily metabolisable energy requirements for the foetus (calf with a birth weight of 40 kg) and uterus (the gravid uterus) during pregnancy

Month of gestation	Energy required by the gravid uterus (MJ/d)
1	Less than 1
2	Less than 1
3	1
4	2
5	3
6	5
7	9
8	17
9	33
At term	43

See Equation 3 on page 16.31.

ENERGY REQUIREMENTS FOR MILK (ME_{milk})

Look-up Table 4 gives the energy needed to produce a litre or a kilogram of milk with a range of fat and protein tests.

The data apply to a dietary concentration of 11 MJ/kg DM and a milk lactose concentration of 4.9%.

As a generalisation, if the feed was 10 MJ instead of 11, each milk energy value should be increased by 0.1 MJ. If the feed was 12 MJ, milk energy values should be decreased by 0.1 MJ.

Look-up Table 4: The energy needed per litre or kilogram of milk of varying composition when dietary metabolisable energy is 11 MJ/kg DM

Fat (%)	Protein (%)									
	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4
	MJ/kg of milk									
3.0	4.2	4.3	4.3	4.4	4.5	4.6	4.6	4.7	4.8	4.9
3.2	4.3	4.4	4.5	4.5	4.6	4.7	4.8	4.9	4.9	5.0
3.4	4.4	4.5	4.6	4.7	4.7	4.8	4.9	5.0	5.1	5.1
3.6	4.5	4.6	4.7	4.8	4.9	4.9	5.0	5.1	5.2	5.3
3.8	4.7	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.3	5.4
4.0	4.8	4.9	4.9	5.0	5.1	5.2	5.3	5.3	5.4	5.5
4.2	4.9	5.0	5.1	5.1	5.2	5.3	5.4	5.5	5.5	5.6
4.4	5.0	5.1	5.2	5.3	5.4	5.4	5.5	5.6	5.7	5.7
4.6	5.2	5.2	5.3	5.4	5.5	5.6	5.6	5.7	5.8	5.9
4.8	5.3	5.4	5.4	5.5	5.6	5.7	5.8	5.8	5.9	6.0
5.0	5.4	5.5	5.6	5.6	5.7	5.8	5.9	6.0	6.0	6.1
5.2	5.5	5.6	5.7	5.8	5.8	5.9	6.0	6.1	6.2	6.2
5.4	5.6	5.7	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.4
5.6	5.8	5.9	5.9	6.0	6.1	6.2	6.2	6.3	6.4	6.5
5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.4	6.4	6.5	6.6
6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.6	6.7	6.7

See Equation 4 on page 16.32.

ENERGY REQUIREMENTS TO GAIN ONE BODY CONDITION SCORE

The following tables show how much energy is needed over and above maintenance and other processes for a cow to gain one body condition score.

This has been done for lactating and dry cows and clearly shows that it takes much more energy to put on a body condition score when cows are dry than when they are lactating, because energy is used less efficiently during the dry period.

It is also clear that bigger cows need more ME to achieve a change in body condition score, and this increases as body condition score increases.

The ME needed to improve body condition score can be used in conjunction with the concentration of ME in the diet to determine how much additional DM must be provided to cows to achieve specific goals.

This exercise clearly shows the futility of attempting to put condition on dry cows quickly with a diet with a ME concentration of only 8 MJ/kg DM.

See page 16.30.

Look-up Table 5 a: Metabolisable energy associated with an increase in body condition in lactating and dry cows that are in condition score 3 on the eight-point scale				
	Jersey (J)	**F x J**	**Friesian (F)**	**Holstein**
Standard reference weight (kg)	400	475	550	650
Live weight/condition score (kg)	36	43	50	59
Empty body gain (EBG; kg)/CS	33	39	46	54
MJ net energy (NE)/kg EBG	25	25	25	25
Lactating cows				
k_g	0.60	0.60	0.60	0.60
MJ metabolisable energy/kg EBG	42	42	42	42
MJ ME/CS	1390	1640	1930	2270
Dry cows				
Dietary ME (MJ/kg DM)	8.0	8.0	8.0	8.0
k_g	0.34	0.34	0.34	0.34
MJ metabolisable energy/kg EBG	74	74	74	74
MJ ME/CS	2440	2890	3400	4000
Dietary ME (MJ/kg DM)	10.0	10.0	10.0	10.0
k_g	0.43	0.43	0.43	0.43
MJ metabolisable energy/kg EBG	58	58	58	58
MJ ME/CS	1910	2260	2670	3130
Dietary ME (MJ/kg DM)	12.0	12.0	12.0	12.0
k_g	0.52	0.52	0.52	0.52
MJ metabolisable energy/kg EBG	48	48	48	48
MJ ME/CS	1580	1870	2210	2590

Look-up Table 5 b: Metabolisable energy associated with an increase in body condition in lactating and dry cows that are in condition score 4 on the eight-point scale

	Jersey (J)	F x J	Friesian (F)	Holstein
Standard reference weight (kg)	400	475	550	650
Live weight/condition score (kg)	36	43	50	59
Empty body gain (EBG; kg)/CS	33	39	46	54
MJ net energy (NE)/kg EBG	26	26	26	26
Lactating cows				
k_g	0.60	0.60	0.60	0.60
MJ metabolisable energy/kg EBG	44	44	44	44
MJ ME/CS	1450	1720	2020	2380
Dry cows				
Dietary ME (MJ/kg DM)	8.0	8.0	8.0	8.0
k_g	0.34	0.34	0.34	0.34
MJ metabolisable energy/kg EBG	78	78	78	78
MJ ME/CS	2570	3040	3590	4210
Dietary ME (MJ/kg DM)	10.0	10.0	10.0	10.0
k_g	0.43	0.43	0.43	0.43
MJ metabolisable energy/kg EBG	61	61	61	61
MJ ME/CS	2010	2380	2810	3290
Dietary ME (MJ/kg DM)	12.0	12.0	12.0	12.0
k_g	0.52	0.52	0.52	0.52
MJ metabolisable energy/kg EBG	51	51	51	51
MJ ME/CS	1680	1990	2350	2750

Look-up Table 5 c: Metabolisable energy associated with an increase in body condition in lactating and dry cows that are in condition score 5 on the eight-point scale

	Jersey (J)	F x J	Friesian (F)	Holstein
Standard reference weight (kg)	400	475	550	650
Live weight/condition score (kg)	36	43	50	59
Empty body gain (EBG; kg)/CS	33	39	46	54
MJ net energy (NE)/kg EBG	28	28	28	28
Lactating cows				
k_g	0.60	0.60	0.60	0.60
MJ metabolisable energy/kg EBG	46	46	46	46
MJ ME/CS	1520	1790	2120	2480
Dry cows				
Dietary ME (MJ/kg DM)	8.0	8.0	8.0	8.0
k_g	0.34	0.34	0.34	0.34
MJ metabolisable energy/kg EBG	81	81	81	81
MJ ME/CS	2670	3160	3730	4470
Dietary ME (MJ/kg DM)	10.0	10.0	10.0	10.0
k_g	0.43	0.43	0.43	0.43
MJ metabolisable energy/kg EBG	64	64	64	64
MJ ME/CS	2110	2500	2940	3460
Dietary ME (MJ/kg DM)	12.0	12.0	12.0	12.0
k_g	0.52	0.52	0.52	0.52
MJ metabolisable energy/kg EBG	53	53	53	53
MJ ME/CS	1750	2070	2440	2860

ENERGY FOR CONDITION GAIN

MJ ME required to gain one condition score in **lactating** cows

MJ ME required to gain one condition score in **lactating** cows				
		Starting condition score		
	SRW (kg)	3	4	5
Jersey	400	1390	1450	1520
F x J	475	1640	1720	1790
Fresian	550	1930	2020	2120
Holstein	650	2270	2380	2480

MJ ME required to gain one condition score in **dry** cows				
SRW (kg)	**Diet ME MJ/kg DM**	**Starting condition score**		
		3	4	5
400	8	2440	2570	2670
400	10	1910	2010	2110
400	12	1580	1680	1750
475	8	2890	3040	3160
475	10	2260	2380	2500
475	12	1870	1990	2070
550	8	3400	3590	3730
550	10	2670	2810	2940
550	12	2210	2350	2440
650	8	4000	4210	4470
650	10	3130	3290	3460
650	12	2590	2750	2860

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WORKED EXAMPLE – ENERGY REQUIRED FOR MAINTENANCE

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

Equation 1 Metabolisable energy requirements for the maintenance (ME_m) of dairy cows		
ME_m (MJ/day) = K.S.M.(0.28W$^{0.75}$.exp(-0.03A))/k_m + 0.1ME_p		
K	= 1.4 for *Bos taurus* animals	K = 1.4
S	= 1.0 for females and 1.15 for bulls	S = 1.0
M	= 1 + (0.23 x proportion of digestible energy from milk)	M = 1.0
W	= live weight (kg)	W = 600
A	= age in years, with a maximum value of 6.0	A = 4
k_m	= net efficiency of use of ME for maintenance k_m = (0.02 x average ME of diet) + 0.5 Varies with the ME concentration of the diet	k_m = (0.02 x 11.5) + 0.5 = 0.73
ME_p	ME_p = amount of dietary ME (MJ) being used directly for production	ME_p = 94 (from equation 4)

Worked example:
ME_m = K x S x M x (0.28 x W$^{0.75}$ x exp(-0.03 x A)) ÷ k_m + (0.1 x ME_p)
ME_m = 1.4 x 1 x 1x (0.28 x 600$^{0.75}$ x exp(-0.03 x 4)) ÷ 0.73 + (0.1 x 94)
ME_m = 67 MJ
E_{graze} = 10% of ME_m
E_{graze} = 7 MJ
ME_m (including E_{graze}) **= 74 MJ ME**

See look-up tables 1 a-e (p16.17–18); also see 'Equation 1 Metabolisable energy requirements for the maintenance (MEm) of dairy cows' (p16.6)

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WORKED EXAMPLE – ACTIVITY – WALKING TO AND FROM THE DAIRY

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

Equation 2 Energy used when walking to and from the dairy each day

Horizontal activity (HA) = (0.0026 x distance x W)/k_m
Vertical activity (VA) = (0.028 x (distance x vert.) x W)/k_m

W	= Live weight Horizontal and vertical components based on live weight (W)	W = 600
HA	= the energy cost associated with horizontal activity	HA = (0.0026 x distance x W) ÷ k_m HA = (0.0026 x 4 x 600) ÷ 0.73 HA = 8.55
VA	= the energy cost associated with vertical activity	VA = (0.028 x (distance x vert) x W) ÷ k_m VA = (0.028 x (4 x 0.04) x 600) ÷ 0.73 VA = 3.7
Walking (horizontal component)	= 2.6 kJ/kilometre per kg W	
walking (vertical component)	= 28 kJ/kilometre per kg W	
Distance	= the distance (kilometres) walked per day when away from the paddock	distance = 4
vert.	accounts for variation in the gradation of terrain and is defined by the kilometre vertical climb per kilometre walked (flat: 0.001; undulating: 0.04; steep: 0.1)	vert = 0.04
k_m	= the efficiency of use of ME for maintenance	km = 0.73 (from equation 1)

Worked example:
Energy for activity = VA + VH
Energy for activity = 8.55 + 3.7
$ME_{activity}$ = 12 MJ ME

See look-up table 2 (p16.20); also see 'Equation 2 Energy used when walking to and from the dairy each day' (p16.30)

WORKED EXAMPLE
– ENERGY REQUIRED FOR PREGNANCY

This equation is written in a format easily transferred to a spreadsheet for calculation.

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

Equation 3 Metabolisable energy requirement for pregnancy $ME_{pregnancy}$

$ME_{pregnancy}$ =
349.16*0.0000576*EXP(-0.0000576*t)*SBW*EXP(349.22-349.16*EXP(-0.0000576*t))/k_c

SBW	= scaled birth weight, which is the ratio of expected birth weight of the foetus to a standard 40 kg Holstein-Friesian calf	SBW = 40kg
t	= time (days) after conception	t = 6 x 30 = 180 days
k_c	= the efficiency of use of ME for conceptus energy gain (k_c = 0.133)	k_c = 0.133

Worked example (equation 3):

$ME_{pregnancy}$ = 349.16 x 0.0000576 x exp(-0.0000576 x t) x SBW x exp(349.22 – 349.16 x exp(-0.0000576 x t)) ÷ k_c

$ME_{pregnancy}$ = 349.16 x 0.0000576 x exp(-0.0000576 x 180) x 40 x exp(349.22 – 349.16 x exp(-0.0000576 x 180)) ÷ 0.133

$ME_{pregnancy}$ = 6 MJ ME

See look-up table 3 (p16.22); also see 'Equation 3 Metabolisable energy requirement for pregnancy $ME_{pregnancy}$' (p16.31)

WORKED EXAMPLE – ENERGY REQUIREMENTS FOR MILK PRODUCTION

This equation is the energy required to produce 1 litre of milk, and it needs to be multiplied by daily milk volume.

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

Equation 4 Metabolisable energy used milk production – ME_{milk}

$ME_{milk} = (0.381 \times F + 0.245 \times P + 0.165 \times L)/k_l$

F	= milk fat (%)	F = 3.6
P	= milk protein (%)	P = 3.2
L	= milk lactose (%)	L = 4.9 (assumed)
k_l	= 0.02 x ME concentration of the diet + 0.4 The net efficiency of use of ME for milk production by cows (k_l) varies directly with the ME concentration in the diet.	k_l = 0.02 x ME of diet + 0.4 = 0.02 x 11.5 + 0.4 = 0.63

In practice, milk lactose is often not readily available, therefore, by assuming an average lactose concentration of 4.9%, this equation becomes:

$ME_{milk} = (0.381 \times F + 0.245 \times P + 0.8085)/k_l$

Worked example:

kg = (daily production in litres) = 20

ME_{milk} (per kg) = (0.381 x F + 0.245 x P + 0.165 x L) ÷ k_l)

ME_{milk}(per kg) = (0.381 x 3.6 + 0.245 x 3.2 + 0.165 x 4.9) ÷ 0.63)

ME_{milk}(per kg) = (1.3716 + 0.784 + 0.8085) ÷ 0.63

ME_{milk} = 4.7 MJ/kg x 20 kg per day

Total ME_{milk} = 94 MJ ME

See look-up table 4 (p16.23); also see 'Equation 4 Metabolisable energy used milk production – ME_{milk}' (p16.32)

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CALCULATING REQUIREMENTS FOR CONDITION GAIN

The process for estimating the ME requirements for condition gain in lactating dairy cows using changes in condition score.

	Process for calculations	CSIRO (2007)
1	kg of LW per BCS	= 0.09 x SRW
2	Kg EBG per BCS	= 0.92 x kg LW per BCS
3	ME per kg EBG gain	= (21.4 + (1.24 x Starting BCS)) ÷ k_g
4	ME per BCS	= ME per kg EBG x kg EBG per BCS
5	△ BCS	= end BCS – start BCS
6	ME per day for BCS gain	= ME per BCS x △ BCS ÷ days
SRW	= Standard Reference Weight (what the cow weighs when mature and at BCS 5)	SRW = 600kg
BCS	= body condition score	Start BCS = 4.5
LW	= live weight	End BCS = 5
EBG	= Empty body gain	
k_g	In lactating cows = 0.6 In dry cows = 0.043 x ME of diet	k_g = 0.6
days	= number of days from start BCS to end BCS	Days = 90

Worked example:
1. kg of LW per BCS = 0.09 x SRW
kg of LW per BCS = 0.09 x 600 = 54
2. Kg EBG per BCS = 0.92 x kg LWperBCS
Kg EBG per BCS = 0.92 x 54 = 49.7
3. ME per kg EBG gain = (21.4 + (1.24 x Starting BCS)) ÷ kg
ME per kg EBG gain = (21.4 + (1.24 x 4.5)) ÷ 0.6 = 45
4. ME per BCS = ME per kg EBG x kg EBG per BCS
ME per BCS = 45 x 49.7 = 2,237
5. △ BCS = end BCS – start BCS
△ BCS = 5 – 4.5 = 0.5
6. ME per day for BCS gain = ME per BCS x △ BCS ÷ days
ME per day for BCS gain = 2,237 x 0.5 ÷ 90 = 12 MJ ME
$ME_{BCS\ gain}$ = 12 MJ ME

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CALCULATING REQUIREMENTS FOR CONDITION GAIN – WORKED FOR EXAMPLE COW

The process for estimating the ME requirements for condition gain in lactating dairy cows using changes in condition score.

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

16

	Process for calculations	CSIRO (2007)
1	kg of LW per BCS	= 0.09 x SRW
2	Kg EBG per BCS	= 0.92 x kg LW per BCS
3	ME per kg EBG gain	= (21.4 + (1.24 x Starting BCS)) ÷ k_g
4	ME per BCS	= ME per kg EBG x kg EBG per BCS
5	$\triangle$ BCS	= end BCS – start BCS
6	ME per day for BCS gain	= ME per BCS x $\triangle$ BCS ÷ days
SRW	= Standard Reference Weight (what the cow weighs when mature and at BCS 5)	SRW = 600kg
BCS	= body condition score	Start BCS = 4.5
LW	= live weight	End BCS = 5
EBG	= Empty body gain	
k_g	In lactating cows = 0.6 In dry cows = 0.043 x ME of diet	k_g = 0.6
days	= number of days from start BCS to end BCS	Days = 90

For the example cow, daily ME requirements =
$ME_{\text{maintenance (including Egraze)}}$ = 74 MJ ME
Plus
ME_{activity} = 12 MJ ME
Plus
$ME_{\text{pregnancy}}$ = 6 MJ ME
Plus
ME_{milk} = 94 MJ ME
Plus
$ME_{\text{BCS gain}}$ = 12 MJ ME
***Equals* 198 MJ ME per day**

CALCULATING CONTRIBUTION FROM CONDITION LOSS

The process for estimating the ME requirements for tissue mobilisation in lactating dairy cows using changes in condition score.

	Process for calculations	CSIRO (2007)
1	kg of LW per BCS	= 0.09 x SRW
2	Kg EBG per BCS	= 0.92 x kg LW per BCS
3	Ave BCS	= (Start BCS + End BCS) ÷ 2
4	ME for milk per kg EBG loss	= (21.4 + (1.24 x Ave BCS)) x 0.84 ÷ k_l
5	ME for milk per BCS	= ME per kg EBG x kg EBG per BCS
6	△ BCS	= end BCS – start BCS
7	ME per day for milk from BCS loss	= ME per BCS x △ BCS ÷ days
SRW	= Standard Reference Weight (what the cow weighs when mature and at BCS 5)	SRW = 600kg
BCS	= body condition score	Start BCS = 5 End BCS = 4.5
LW	= live weight	
EBG	= Empty body gain	
K_l	= 0.6	k_l = 0.6
days	= number of days from start BCS to end BCS	Days = 90

Worked example:

1. kg of LW per BCS = 0.09 x SRW
   kg of LW per BCS = 0.09 x 600 = 54
2. Kg EBG per BCS = 0.92 x kg LWperBCS
   Kg EBG per BCS = 0.92 x 54 = 49.7
3. Ave BCS = (Start BCS + End BCS) ÷ 2
   Ave BCS = (5 + 4.5) ÷ 2 = 4.75
4. ME per kg EBG loss = (21.4 + (1.24 x Ave BCS)) x 0.84 ÷ k_l
   ME per kg EBG loss = (21.4 + (1.24 x 4.75)) x 0.84 ÷ 0.6 = 38
5. ME per BCS = ME per kg EBG x kg EBG per BCS
   ME per BCS = 38 x 49.7 = 1,889
6. △ BCS = end BCS – start BCS
   △ BCS = 4.5 – 5 = -0.5
7. ME per day for milk from BCS loss = ME per BCS x △ BCS ÷ days
   ME per day for milk from BCS loss = 1,889 x -0.5 ÷ 90 = -11 MJ ME
   ME_{BCS} loss = -11 MJ ME

ENERGY FROM CONDITION LOSS

MJ ME available for milk production from the loss of one condition score in **lactating** cows			
SRW (kg)	**Starting condition score**		
	6	5	4
400	1337	1280	1222
475	1588	1520	1451
550	1839	1760	1681
650	2173	2080	1986

CALCULATING REQUIREMENTS FOR CONDITION LOSS – WORKED FOR EXAMPLE COW

Example cow details

600 kg Holstein	4 years of age
Late lactation	Gaining 0.5 CS over the last 90 days of lactation, starting from CS 4.5
6 months pregnant	Walking 4 km per day over undulating terrain
Producing 20 litres at 3.6% fat and 3.2% protein	Estimated diet quality of 11.5 MJ ME/kg DM
Grazing	

So, if our example cow was losing condition rather than gaining condition (with all other parameters the same), daily energy requirement from the diet would equal as per the following table.

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	Process for calculations	CSIRO (2007)
1	kg of LW per BCS	= 0.09 x SRW
2	Kg EBG per BCS	= 0.92 x kg LW per BCS
3	Ave BCS	= (Start BCS + End BCS) ÷ 2
4	ME for milk per kg EBG loss	= (21.4 + (1.24 x Ave BCS)) x 0.84 ÷ k_l
5	ME for milk per BCS	= ME per kg EBG x kg EBG per BCS
6	△ BCS	= end BCS – start BCS
7	ME per day for milk from BCS loss	= ME per BCS x △ BCS ÷ days
SRW	= Standard Reference Weight (what the cow weighs when mature and at BCS 5)	SRW = 600kg
BCS	= body condition score	Start BCS = 5 End BCS = 4.5
LW	= live weight	
EBG	= Empty body gain	
K_l	= 0.6	k_l = 0.6
days	= number of days from start BCS to end BCS	Days = 90

Worked example:

$ME_{\text{maintenance (including Egraze)}}$ = 74 MJ ME
Plus
ME_{activity} = 12 MJ ME
Plus
$ME_{\text{pregnancy}}$ = 6 MJ ME
Plus
ME_{milk} = 94 MJ ME
Plus
$ME_{\text{BCS gain}}$ = -11 MJ ME
Equals **175 MJ ME per day**

17 COW REQUIREMENTS FOR PROTEIN

The amount of protein a cow needs depends on its size, growth, milk production and stage of pregnancy. Of these processes, milk production has the major influence on protein requirements.

Protein is measured as crude protein, or rumen degradable protein (RDP) and undegradable protein (UDP).

When calculating the protein requirements of a herd, either crude protein, RDP and UDP values or metabolisable protein can be used.

For details on the different systems used to describe protein requirements of the cow and the protein supplied in feeds, see Ch 4.

Crude protein is a measured value (nitrogen x 6.25).

At best, RDP and UDP can only be considered as guesstimates.

CALCULATING RDP & UDP

To work out how much RDP and UDP are required, consider the protein requirements of the rumen microbes. The microbial protein made available (after it is flushed from the rumen) also needs to be calculated.

Any shortfall in protein can then be made up by other protein sources (that is, UDP). Remember though, not all microbial protein or UDP eaten becomes available to the cow.

Factors such as digestibility of amino acids reaching the small intestine as well as feed intake will influence the type and amount of protein eventually available to the cow.

Where grazed pasture is part of a cow's diet, it is very difficult to estimate, so use the percentages of crude protein guidelines on protein requirements as given in the table on the next page.

For further information into protein requirements, see CSIRO Excel spreadsheet, CP_ Required, found by searching *CP. Required – CSIRO GrazPlan*.

Results for pastures analysed in Victoria reveal that 20–30% of pasture protein is likely to be UDP, or bypass protein.

This means that it is unlikely that cows grazing good-quality pasture and producing less than 30 L/day will need to be supplemented with additional UDP.

Some nutritionists like to supplement 20–30 L cows in early lactation with protein to help drive appetite. However, the feeding system must be able to accommodate an increase in intake otherwise cows will tend to mobilise more tissue than they would otherwise, thereby creating potential issues with reproductive performance.

In this situation, increases in intake are more likely to be achieved in a feed-lot than in a grazing system.

The table below shows crude protein requirements at different stages of the lactation cycle.

Crude protein requirements of a cow at different stages of lactation

Milk production	CP % in diet DM
Early lactation	16–18%
Midlactation	14–16%
Late lactation	12–14%
Early dry period	12–14%
Pre-calving transition period	14–16%

Note that since there may be young animals in a herd that are still growing, the dry cow requirements could increase slightly.

REQUIREMENT FOR UDP

Above 12 L milk production, some protein in the diet must be undegradable protein (UDP).

There is a limit to the rumen's capacity to use rumen degradable protein (RDP) to produce microbial protein which can then be flushed through to the small intestine for digestion.

Microbial protein coming out of the rumen can sustain milk production to 12 L. However, for milk production above 12 L, at least some protein must be UDP. The need for UDP increases as milk production rises.

RECOMMENDATIONS FOR PROTEIN LEVELS

Recommendations for protein levels in a typical total mixed ration overseas suggest the diet for high-producing cows should contain 18% of the diet DM as crude protein, of which 65% is degradable in the rumen, 35% by-passes the rumen and 32% is soluble.

Many Australian pastures have 20–30% protein, of which 80–90% is potentially degradable in the rumen, 10–20% is by-pass, and 30–40% is soluble. Therefore, in theory, the protein profile of high-quality pasture does not meet recommended levels.

In practice, high-protein pastures actually can meet the protein requirements for high levels of milk solids production. Despite the highly degradable nature of pasture protein, the required amount of metabolisable protein can be supplied because:

- rumen microbes grow extremely well on high quality pasture
- the high passage rate out of the rumen (4–7%/hour) means that a significant amount of potential RDP passes out of the rumen before being degraded, thereby becoming UDP.

In most instances where an imbalance of metabolisable protein has been corrected, and access to all or part of the food has been ad lib, food intake has increased with a corresponding increase in milk yield. However, this sort of response is rarely seen in grazing cows because pasture availability may limit increases in intake.

Moreover, it is often likely that the protein content of a pasture sward is considerably in excess of requirements, and animals actually have to expend energy excreting the excess.

Green leafy pastures usually provide an excess of crude protein which the cow must excrete.

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COW REQUIREMENTS FOR FIBRE

Fibre is required in a cow's diet to maintain normal rumen function and help prevent a depression of milk fat.

Assessing the adequacy of dietary fibre in dairy cows is difficult. This is because the physical effectiveness of a diet to maintain proper rumen conditions, health and production performance depends on various factors including the following.

- Fibre content – physically effective fibre describes the effectiveness of fibre to promote chewing and saliva production. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) are chemical measures of fibre (hemi-cellulose, cellulose and lignin) in a feed but do not describe the feed's physical characteristics that promote chewing and salvia production.
- Forage particle size – fine particle size may adversely affect stratification of ruminal digesta, providing fewer stimuli for chewing activity and ruminal contractions. This may result in a reduced ruminal pH, depressed fibre digestion and feed intake, as well as lowered feed efficiency.
- Starch fermentability – rapidly digested carbohydrates increase the requirement for effective fibre in dairy cow diets. Avoid slug feed of rapidly fermentable feeds.

See below for the recommended level of fibre to stimulate chewing and saliva production. This helps to buffer the rumen pH and promote growth of the rumen microbes.

Recommended minimum fibre requirements for dairy cows on pasture	
Good quality all-pasture diet	**NDF % in diet DM**
Minimum NDF	35 %
Minimum physically effective fibre peNDF	17 %
Minimum ADF	19-21 %
Source: Kolver 2000.	

In practice, these benchmarks require modification for pasture diets because the fibre levels in fresh pasture are much higher than 30%. This fibre is much more fermentable (only 40–50% of the NDF in good-quality pasture may be 'effective').

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peNDF = physically effective neutral detergent fibre

peNDF of a feedstuff is the product of its NDF concentration and physical effectiveness factor (pef)

The recommended level of fibre for a cow fully fed on a total mixed ration is a minimum of 27–33% NDF to stimulate chewing and saliva production. This in turn helps to buffer the rumen pH and promote growth of the rumen microbes.

Recommended minimum fibre requirements for dairy cows on pasture plus supplements or TMR	
Pasture + supplement; total mixed ration	**NDF % in diet DM**
Minimum NDF	27-33 %
Minimum physically effective fibre peNDF	20 %
Minimum ADF	19-21 %
Source: Kolver 2000.	

For pasture diets that include a high proportion of starchy supplement (e.g. more than 25–30% of the diet as grain)

Recommended minimum total mixed ration fibre levels of 27–33% NDF and effective fibre levels of 20% are applicable.

There are probably three reasons for the difference between the recommendations for pasture and overseas recommendations that are based on high concentrate and TMR diets.

First, when starchy concentrates are fed, the rumen becomes more acidic because lactate (or lactic acid) is produced as well as the normal volatile fatty acids. Lactate depresses microbial growth to a much greater extent than volatile fatty acids and also causes acidosis-related health problems such as laminitis.

Second, when starchy feeds are fed, those rumen microbes that can digest both fibre and starch will preferentially digest starch, thereby reducing fibre digestion.

There is no slug feeding of concentrates in a TMR fed to appetite, so a spike of acid production does not need to be managed through more saliva buffer.

PHYSICALLY EFFECTIVE NDF (peNDF)

The peNDF of a feedstuff is the product of its neutral detergent fibre (NDF) concentration and physical effectiveness factor (pef).

The physical effectiveness factor (pef) adjusts NDF for physical effects. The physical effectiveness factor (pef) is primarily related to particle size, but the following physical factors may also be important:

- particle shape
- particle density
- fibre fragility (ease of breakdown)
- fibre stiffness or brittleness.

Standardised pef values based on chewing as tabulated by Mertens (1997) are as per the table on the next page.

By definition, physical effectiveness factor varies from:

- 0 – when NDF is not physically effective at all
- 1 – when NDF is fully effective in promoting chewing and rumen buffering.

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peNDF	=	peF X NDF
physically effective neutral detergent fibre	**=**	**physical effectiveness factor**

Physical effectiveness factors (pef) for NDF in feeds of various physical form classifications based on total chewing activity in relation to that elicited by long grass hay

Feed and physical form	Standardised pef
Grass hay	
Long	1.00
Coarsely chopped	0.95
Medium chopped	0.90
Dried	0.80
Ground or pelleted	0.40
Grass silage	
Coarsely chopped	0.95
Medium chopped	0.90
Finely chopped	0.85
Maize silage	
Coarsely chopped	0.90
Medium chopped	0.85
Finely chopped	0.80
Lucerne hay	
Long	0.95
Coarsely chopped	0.90
Medium chopped	0.85
Finely chopped	0.70
Ground or pelleted	0.40
Lucerne silage	
Coarsely chopped	0.85
Medium chopped	0.80
Finely chopped	0.70
Non-forage fibre sources	0.40
Barley grain	
Rolled	0.70
Coarsely ground, rolled	0.60
Medium ground	0.40
Complex mixtures	
Ground	0.40
Pelleted	0.30

Source: Mertens 1997.

A simple system for estimating peNDF from chemical and physical measurements in the laboratory can be based on NDF concentration and the proportion of particles that are retained on a 1.18 mm sieve.

Mertens (1997) used long grass hay as the standard against which the physical effectiveness factor of all other NDF sources was calculated. If it is assumed that pef is equal to the proportion of particles retained on a 1.18 mm sieve, then peNDF can be estimated by multiplying NDF concentration by the proportion of particles retained on the sieve.

Some examples of this have been reported by Mertens (1997) and are given in the table below.

Using this approach, the peNDF requirement of high-producing dairy cows fed a total mixed ration is 19–22% of diet DM to maintain an average ruminal pH of about 6.0.

However, dietary peNDF interacts with the starch degradation in the reticulo-rumen, modifying the response of ruminal fermentation and performance in dairy cows.

Some examples of estimating the peNDF of feeds using chemical and physical measurements in the laboratory

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Feed	NDF (% of DM)	1.18-mm sieve (fraction retained)	peNDF (% of DM)
Standard	100	1.00	100
Grass hay	65	0.98	64
Legume hay	50	0.92	46
Legume silage, coarse chop	50	0.82	41
Legume silage, fine chop	50	0.67	34
Maize silage	51	0.81	42
Brewers grains	46	0.18	8
Maize grain, ground	9	0.48	4
Soybean meal	14	0.23	3
Soybean hulls	67	0.03	2
Rice mill feed	56	0.005	0.3

Source: Mertens 1997.

A review by Zebeli et al. (2010) concluded that a ratio between peNDF and ruminally degradable starch of grains or concentrates lower than about 1.45 should be avoided when formulating diets for lactating dairy cows.

This is sufficient to maintain a daily mean ruminal pH of 6.2, which lowers the risk of sub-acute rumen acidosis (SARA) and prevents milk fat depression without exerting any negative effects on DM intake or milk production.

Part of the difficulty in assigning fibre requirements is related to defining the response to be optimised. Fibre is needed in the diet of cows to keep them fit and healthy, but maintaining milk fat percentage has been the focus of much of the research that has been undertaken.

ADVISER ALERT

Recommended levels of fibre vary depending on many factors.

- Too much fibre decreases intake.
- Energy and protein density of the diet are also decreased and this has the potential to limit production.

Recommendation for fibre in the diet is usually defined as a minimum to maintain rumen health.

Although current knowledge on peNDF is extremely limited for pasture, the hope is that this can be rectified in the future so that improved recommendations can be provided.

As demonstrated by Mertens (1997), NDF requirements can depend on what aspect of animal productivity needs to be optimised: see the tables below.

The higher requirement for peNDF to maintain ruminal pH at 6.0 than to maintain 3.4% milk fat indicates the difficulty in defining an absolute requirement for fibre.

Estimates of the physically effective fibre (peNDF) required to maintain milk fat percentage in early to mid lactation

Requirements for specified milk fat percentages	peNDF (% of DM)
3.6% milk fat	24.0
3.4% milk fat	19.7
3.2% milk fat	16.4

Source: Mertens 1997.

Estimates of the physically effective fibre (peNDF) required to maintain a specified average ruminal pH

Requirements for a specified average ruminal pH	peNDF (% of DM)
6.2	30.0
6.1	25.6
6.0	22.3
5.9	19.3

Source: Mertens 1997.

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19

COW REQUIREMENTS FOR MINERALS

As the milk production levels of cows have continued to increase, the purpose of supplementing diets with minerals is no longer just to avoid obvious clinical mineral deficiencies, but to meet daily mineral requirements for optimal cow health, fertility and production.

The mineral requirements of cows are often underestimated. Replacing minerals lost from the cow's body in milk, urine, manure and sweat is critical if you want to optimise immune function, growth rate, fertility and milk production, and avoid metabolic disorders and problems with bones and teeth.

There are 14 minerals that are considered as essential nutrients for cows.

Mineral nutrition of dairy cattle is very complicated. A summary is given here as a starting point.

For further details see:

CSIRO (2007) Nutrient Requirements of Domesticated Ruminants. (Eds Freer M, Dove H, Nolan JV) CSIRO Publishing: Collingwood, Victoria.

Macro minerals: Cows need large amounts (grams per day)	Micro minerals: Cows need small amounts (milligrams per day).
Calcium	Cobalt
Phosphorus	Copper
Magnesium	Iron
Potassium	Iodine
Sodium	Manganese
Chlorine	Zinc
Sulphur	Selenium
Deficiencies of macro minerals can result in acute metabolic disorders such as milk fever or grass tetany that lead to death if not treated promptly.	**Deficiencies of micro minerals are slower to appear and more difficult to diagnose. Most often display as 'poor doers' whose performance picks up when the deficient mineral is supplied.**

It is often difficult to estimate the mineral requirements of cows because the requirement varies according to:

- the absorption efficiency of the mineral
- the production stage and age of the animal
- the environment
- interaction with other minerals.

Gross deficiencies of essential minerals become evident from a variety of clinical signs, as do excesses, but the major problem in practice is generally the recognition of subclinical deficiencies.

Sub-clinical deficiencies are frequently transient and may reduce animal production with few specific signs. The realisation of a mineral deficiency may be delayed by the ability of the animal to utilise body reserves (such as calcium) or stored excesses (such as copper), often for periods of weeks or months.

A further complication is that, in a number of instances, the dietary mineral concentration that would be adequate is not well-defined and cannot be predicted reliably from an analysis of the feed.

High-producing herds fed diets high in cereal grain or maize silage are most likely to need some mineral supplementation.

Many mineral deficiencies are less likely in low-to-moderate producing herds fed predominantly pasture.

Interactions between minerals

There are a large number of interactions amongst minerals and other constituents in the diet that may affect availability and utilisation or retention.

Since interactions between minerals can have serious implications for the provision of particular minerals, it is important that they are recognised, particularly in relation to mineral concentrations in pastures.

For example, it is evident that potassium levels in pasture are considerably higher than those required by the animal. Such levels may have direct implications on magnesium absorption which, in turn, may affect calcium intake.

The major interactions between minerals are summarised in the table below.

Possible mineral interactions

Mineral	Interfering factor
Calcium	Phosphorus, vitamin D, magnesium, iron, manganese, zinc
Phosphorus	Calcium, vitamin D, phytic acid, iron, manganese
Magnesium	Potassium, calcium, phosphorus, zinc, nitrogen (in plants)
Potassium	Magnesium, sodium
Sodium	Potassium
Sulphur	Copper, selenium
Iron	Calcium, phosphorus, copper, zinc
Copper	Molybdenum, organic and inorganic sulphur, zinc, iron
Zinc	Calcium, copper, iron, phosphorus, magnesium, lead
Iodine	Goitrogens
Selenium	Vitamin E, ferrous iron
Cobalt	Iron, iodine
Manganese	Calcium, phosphorus, iron

Source: Stockdale.

COW REQUIREMENTS FOR CALCIUM

Calcium is the most common mineral in the cow, with about 99% of the body's calcium present in bone and teeth.

Calcium metabolism is complex and highly controlled.

The amount of calcium absorbed from the intestines, and its concentration in the blood, is regulated by the interaction between parathyroid hormone, calcitonin and vitamin-D metabolites, particularly 1,25-dihydroxycholecalciferol.

As animals age, absorption declines due to the intestines and bones both becoming less responsive to vitamin D.

Inflow of calcium to blood	Outflow of calcium from blood
• Inflow occurs through absorption from the digestive tract and resorption from bones. • An increase in plasma calcium concentration stimulates the secretion of calcitonin from the thyroid gland. • This reduces resorption from the bone and absorption from the intestines.	• Outflow occurs through deposition in tissue (mainly bone), secretion in milk, and excretion through faeces, urine and sweat. • A decrease in plasma calcium concentration increases the secretion of parathyroid hormone, which in turn stimulates the kidneys to convert vitamin D to an active form. • This increases absorption of calcium from the intestines and retention of calcium from the kidneys, and stimulates resorption of calcium from the bone.

During late pregnancy and particularly early lactation, there is a high demand for calcium, and animals can fall into a negative calcium balance.

Hypocalcaemia (low blood calcium level) results from inadequate gastro-intestinal absorption and bone resorption to satisfy the calcium requirements of milk production.

MILK FEVER IS A 'GATEWAY DISEASE'

If cows have milk fever, they are more likely to suffer other animal health problems around calving such as ketosis, displaced abomasum, dystocia, retained foetal membranes, metritis and mastitis.

Targets: Less than 1% of herd, less than 2% of older cows

Milk fever

Acute hypocalcaemia, characterised as 'milk fever', is not uncommon in cows at pasture within the first few days after calving when the requirement for calcium has suddenly and substantially increased.

Milk fever and hypocalcaemia are not solely related to calcium concentrations in feed. They are also influenced by concentrations of other minerals in the diet, namely magnesium, phosphorus and the dietary cation anion difference (which is a function of the diet's potassium, sodium, sulphur and chloride levels), age and breed.

Preventative measures developed to support calcium metabolism and reduce the risk of milk fever around calving include:

- increasing the efficiency of absorption of calcium in cows at the point of calving by feeding a low-calcium, pre-calving transition diet
- supplementing the pre-calving transition diet with magnesium and anionic supplements (salts or acid)
- feeding a pre-calving transition diet which is also low in phosphorus
- administering vitamin D and intravenous calcium fluids.

For further details on formulating pre-calving transition diets, see Ch 21.

ADVISER ALERT – MID-LATE LACTATION MILK FEVER

Milk fever is most commonly seen around calving time. However, it is also sometimes a problem in mid-late lactation.

Mid-late lactation milk fever may occur due to a sudden disruption in calcium and / or magnesium intake / absorption caused by one of the following:

- insufficient dietary mineral supplementation, especially at moderate – high grain/concentrate feeding rates
- dietary mineral imbalance:
  - excessively wide calcium : phosphorus ratio (greater than 7:1 or less than 1:1)
  - insufficient vitamin D (especially in winter)
  - insufficient magnesium
  - excess potassium / insufficient sodium
- interruption or reduction in daily consumption of pasture or supplementary feed (such as oestrus), bad weather
- concurrent disease (such as mastitis), respiratory disease or stress (such as heat)
- disturbance to function of rumen (such as by a sudden change in diet, ruminal acidosis, mycotoxin, poor quality silage)
- ingestion of anything which binds calcium and / or magnesium and reduces their availability in rumen contents for absorption.

The target level for milk fever in dairy herds is <1%.

ADVISER ALERT
– CALCIUM: PHOSPHORUS RATIOS IN MILKER DIETS

Pastures can have relatively high calcium:phosphorus ratios, which may be implicated in increased incidences of hypocalcaemia and reproductive problems.

Calcium intake is increased because superphosphate increases calcium levels of individual pasture species and improves the percentage of clover in pasture.

There is some conflict in the literature with regard to the optimum calcium:phosphorus ratio in milker diets. This is primarily due to differences in absorption efficiency between and within calcium and phosphorus sources and the recycling of phosphorus through saliva.

The ratio generally considered most suitable is between 1:1 and 2:1. However, ruminants can tolerate higher ratios provided their vitamin D status is high.

Some examples of daily dietary calcium allowances are given in the tables on the next page.

Although grazing dairy cows do not often suffer from calcium deficiencies, except around calving, as milk production escalates and increasing amounts of high-energy supplements are fed, it is good insurance to include additional calcium in the diet throughout lactation to help reduce the mining of calcium from the bones that inevitably occurs as cows age.

For both calcium and phosphorus, allowances are referred to rather than requirements because they contain a safety factor.

When diets are being formulated, it is relatively easy and inexpensive to add inorganic forms of either mineral, as required.

Recommended calcium allowances for growth (g/day) for cattle			
Live weight (kg)	**Live weight gain (kg/day)**		
	0	0.5 kg	1.0 kg
150 kg		9.2	16.0
300 kg		11.5	17.7
400 kg		13.7	20.0
500 kg	9.0		

Recommended calcium allowances for pregnancy and milk production (g/day) for cattle	
For pregnancy	
5-6 months	2.3 g
7	5.3 g
8	8.7 g
9	13.2 g
For milk production	
(g/kg)	1.9 g

Note: Pregnancy and milk yield allowances are in addition to maintenance requirements.

Source: CSIRO 2007.

COW REQUIREMENTS FOR PHOSPHORUS

About 80% of phosphorus in the body is found in the bones and teeth. Phosphorus has more known functions within the body than any other element, with many aspects of phosphorus metabolism interrelated with calcium and vitamin D.

Phosphorous absorption occurs in the small intestine and is stimulated by vitamin D.

There is also considerable recycling of phosphorus between the gut and blood, via saliva.

The rate of phosphorus absorption is directly related to phosphorus supply,

The efficiency of absorption differs according to the supply.

Animals with a plasma inorganic phosphorus level of less than 1.3 mmol per L are likely to have depressed feed intakes and may be phosphorus-deficient.

In animals suffering from phosphorus deficiencies, feed intake is depressed, growth rates are poor, milk production decreases, bones soften and reproduction performance may be impaired.

Absorption efficiency is low from phosphorus-deficient diets, but increases with phosphorus supplementation until supply is sufficient to meet requirements. It then decreases at higher rates of phosphorus supply.

The low absorption efficiency at low phosphorus levels may be due to an adverse calcium:phosphorus ratio, whilst at the high phosphorus levels, it could be part of a homeostatic mechanism or due to a progressive saturation of the absorption mechanism.

Phosphorus deficiency is usually secondary to a calcium deficiency and is resolved when the calcium deficiency is overcome. A dietary phosphorus deficiency may be rectified by direct supplementation and/or the treatment of pastures with phosphatic fertilisers.

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The loss of appetite seen in cows with phosphorus deficiency is often paralleled by a craving for abnormal materials such as soil, wood, stones, flesh and bones.

However, these tendencies are not specific to phosphorus deficiency, as they are also observed in animals suffering from a lack of sodium, potassium or calcium.

For those interested in obtaining estimates of calcium and phosphorus allowances in specific instances a spreadsheet program is available. Search for *Ca_P_Required – CSIRO GrazPlan*.

Recommended phosphorus allowances (g/day) for cattle			
Live weight			
(kg)	**Live weight gain (kg/day)**		
	0	0.5 kg	1.0 kg
150 kg		6.2	10.9
300 kg		7.4	11.7
400 kg		8.5	13.2
500 kg	4.3		

Recommended phosphorus allowances (g/day) for pregnancy and milk production for cattle	
For pregnancy	**Phosphorus allowances (g/day)**
5-6 months	1.1 g
7 months	2.2 g
8 months	3.6 g
9 months	5.7 g
For milk production	**Phosphorus allowances (g/day)**
(g/kg)	1.4 g

Note: Pregnancy and milk yield allowances are in addition to maintenance requirements.

Source: CSIRO 2007.

COW REQUIREMENTS FOR MAGNESIUM

Approximately 70% of the total magnesium in a cow's body is found in the skeleton, with the remainder distributed in the soft tissues and fluids. Magnesium is stored in bones, and any excess to requirements is excreted in urine.

In young ruminants, magnesium is efficiently absorbed from the small intestine.

The rumen becomes the major site of absorption once it develops.

In adults, the small and large intestines are the sites of net secretion.

Magnesium stimulates mobilisation of bone calcium and is involved in the activation of vitamin D. Small reductions in plasma magnesium can be associated with significant decreases in the amount of calcium cows can mobilise in response to hypocalcaemia.

Cattle have good homeostatic control for eliminating moderate excesses of magnesium and relatively poor homeostatic control against a deficiency.

Although bone acts as a reserve for magnesium, it is mobilised slowly and can be inadequate to meet daily requirements. Older animals are least able to mobilise magnesium from the skeleton during dietary deficiencies.

The amount of ingested magnesium absorbed varies with age and diet. The coefficient of absorption is high in calves soon after birth, but it falls steeply after weaning.

For cattle grazing spring grass that has been top-dressed with potash and/or nitrogenous fertilisers, magnesium absorption tends to be even lower than normal.

For grazing cattle selecting a diet with about 3% potassium and a DM digestibility of about 75%, estimates of daily requirements of magnesium for growth, pregnancy and milk production are:

- 3 g magnesium/kg live weight gain
- 0.8, 1.4 and 2.2 g magnesium/day in early, mid and late pregnancy
- 0.8 g magnesium/kg milk.

The dietary requirements for housed cattle are about 65% of the values for grazing animals because of the more efficient absorption of magnesium from a diet of hay and concentrates.

Grass tetany

Associated with low plasma magnesium concentrations (0.4 mmol per L) is the condition, hypomagnesaemia, commonly referred to as grass tetany.

Hypomagnesaemia is defined as abnormally low concentrations of magnesium in the blood. It is likely to occur in early lactation when a high proportion of pasture low in magnesium is consumed.

Hypomagnesaemia occurs more frequently where potassium and nitrogen fertilisers have been applied to pastures, or where soils are low in sodium.

Grasses are generally lower in magnesium than legumes, and magnesium availability is lower in fresh grass than in the equivalent grass conserved as hay or silage.

Hypomagnesaemia occurs in acute, subacute and chronic forms. The acute form is characterised by cows showing unusual alertness (twitching of muscles and ears), staggering gait, tetany of limbs, convulsions and eventually death. The subacute form of the disease is more gradual and treatment is usually effective. Chronic hypomagnesaemic cows have low magnesium levels and, while they do not show clinical signs, they can have depressed milk production.

Supplementary magnesium can be provided by drenching, dusting pasture and/or hay with magnesium oxide, magnesium licks, magnesium bullets, addition of magnesium to water troughs or addition of magnesium to the grain component of diets.

Magnesium oxide is inexpensive to add to the diet and supplemental Mg is good insurance in pasture-based diets. However, supplementation with very high amounts of magnesium oxide should be avoided as it may be a risk factor for salmonellosis in dairy cattle.

The target for grass tetany in dairy herds is 0%.

COW REQUIREMENTS FOR POTASSIUM

Potassium is the major intracellular cation and is important in regulating osmotic pressure and acid-base balance.

Deficiencies of potassium are rare in grazing animals due to the high potassium content of pastures.

The upper limit of requirements for potassium reported in the literature is 1.0–1.2% of DM.

Note that pasture in particular is always significantly in excess of this concentration.

Potassium is primarily absorbed in the small intestine with some absorption also occurring through the stomach and hindgut.

Excess potassium is excreted in urine, and some recycling of potassium occurs via secretion into saliva.

Excesses of potassium can induce metabolic alkalosis and contribute to an increased incidence of hypocalcaemia, as well as reduce the absorption and metabolism of magnesium and promote hypomagnesaemia. High potassium concentrations may also cause increased excretion of sodium.

COW REQUIREMENTS FOR SODIUM

Sodium is present in both the skeleton and extracellular fluids. It is the principal cation of extracellular fluids and plays an important role in regulating the composition of blood, saliva and extracellular fluids and the acid-base balance.

The production of milk is the largest drain on sodium reserves in the body, and this can increase up to five-fold if a cow has mastitis.

Animals are able to withstand suboptimal levels of sodium intake for several months before sodium deficiency symptoms occur.

The sodium requirements of mature dairy cattle are generally considered to be about 0.12% of DM for lactating animals and 0.08% of DM for non-lactating ones.

Signs of sodium deficiency include a pica or craving for salt, an unthrifty, haggard appearance and rough coat, loss of body weight and a decrease in milk yield. However, it should be noted that all ruminants commonly exhibit an appetite for salt and this does not necessarily indicate a sodium deficiency.

Salt (sodium chloride) is the most common mineral supplement given to ruminants. The amount of salt that can be tolerated safely by dairy cows has not been clearly established, however, it is suggested that salt be no more than 4% of total DM intake for lactating cows. An adequate water supply is essential, but the salt content of water that produces toxicity is lower (2%) than that of feed.

COW REQUIREMENTS FOR CHLORINE

Sodium is more limiting than chlorine, so if sodium requirements are met, then generally chlorine will be too.

In general, chlorine requirements will be met if there is 0.20–0.24% chlorine in lactating cow diets, and 0.07–0.10% for all other cattle.

Chloride is the major anion of extracellular fluid, including blood plasma and cerebrospinal fluid.

In conjunction with potassium and sodium, chlorine maintains the acid base balance and regulates osmotic pressure.

Chlorine also plays a significant role in gastric secretions. Dietary chlorine is readily available to the animal and is absorbed from the rumen.

Despite the major importance of chlorine, deficiencies have only been observed when animals have been given carefully prepared low-chlorine diets. Deficiencies are unlikely in practice because most feeds contain enough chlorine to at least meet requirements.

As chlorine is generally associated with sodium, it is very difficult to assess requirements separately.

COW REQUIREMENTS FOR SULPHUR

The sulphur requirements for maintenance, growth, pregnancy and lactation have not been clearly defined, but diets containing about 0.15% DM are considered to be adequate. However, sulphur intake from all sources should not exceed 0.4% of dietary DM.

Sulphur is an essential component of animal protein, biotin, thiamine, insulin, coenzyme A and sulphonated polysaccharides.

Sulphur requirements need to be considered with nitrogen, as both must be available for microbial synthesis of sulphur-amino acids.

A nitrogen:sulphur ratio of 14:1 is recommended since this is close to the nitrogen:sulphur ratio found in tissue, microbial cells and milk protein.

COW REQUIREMENTS FOR MICROMINERALS

A summary of the main aspects of each essential micromineral is provided in the following table.

A range of other microminerals (such as arsenic, chromium, nickel, silicon, tin, vanadium, fluorine, cadmium, lead and molybdenum) are also consumed by cattle, but the essentiality of them is often uncertain.

A summary of key information about requirements for the essential micro-minerals

Mineral	Details
Cobalt	• Needed for synthesis of vitamin B_{12} in the rumen. • All symptoms of deficiency are associated with a malfunction of enzymes that require B_{12}. Deficiency leads to a loss in weight and milk production. Toxicities are rare. • There is more in clover than in grasses but concentrations tend to be lower when pasture growth is rapid. Animal requirements for dietary cobalt are between 0.11 and 0.18 mg/kg DM.
Copper	• Required for haemoglobin synthesis and involved in some enzyme and nerve formation. Also required for production of hair pigments and cartilage. • Accumulates in the liver and kidney. Toxicity is uncommon in adults but can affect weight gain in milk-fed calves. • Generally higher in clovers than in grasses. • Net requirements are: maintenance – 4 µg/kg LW; growth – 0.5 mg/kg LW gain; milk – 0.10 mg/L; conceptus – 2 mg/day. • Converting net requirements to dietary requirements is uncertain because the coefficient of absorption is very low, 1-6%. Moreover, concentration in feeds is a poor indicator of capacity to meet requirements because of complex interactions with other compounds.
Iodine	• Required for synthesis of thyroid hormones that regulate the rate of energy metabolism. • Goitrogens found in some herbage (such as thiocyanate in some clovers and glucosinolates in some brassicas) inhibit hormone synthesis. Absorbed very efficiently, with the rumen being the main site of absorption. • Deficiency causes reduced growth rates, reproductive failure and low milk production. Iodised salt licks are good sources of supplemental iodine. • An intake of 0.5 mg of iodine/kg DM should meet requirements.

A summary of key information about requirements for the essential micro-minerals	
Mineral	**Details**
Iron	• Major component of haemoglobin which is required for oxygen transport in the blood. • Excess iron is harmful to copper and phosphorus metabolism. • Daily intakes of 30–40 mg/kg DM should be sufficient to meet requirements, but most feeds have more than is needed anyway.
Manganese	• Has an integral role in several enzymes and is required for bone and cartilage formation and fat and carbohydrate metabolism. Thus, it is essential for growth, skeletal development and reproduction • Excess manganese interferes with iron metabolism, depressing blood concentrations of haemoglobin. • It is not well absorbed, with coefficents of absorption as low as 1%. It is estimated that about 20 mg of manganese/day is needed for skeletal development.
Selenium	• Important in microbial enzymes and tissue protein as well as antibody production (and thus immune function). • Associated with antioxidant activity. Deficiency in adults is linked with retained placenta and muscular weakness after calving. Muscular dystrophy (white muscle disease) associated with selenium and/or vitamin E deficiency in calves. Toxicity causes death. • There are higher levels in grasses than in clover, and organic supplements are preferred to inorganic supplements. • Dietary concentrations of no more than 0.5 mg/kg DM should be sufficient to meet requirements.
Zinc	• Component of many enzymes and involved in many cellular functions. • It is absorbed in the small intestine where the efficiency of absorption is about 40%. • The requirement is 10–20 mg/kg DM.
Source: CSIRO 2007.	

REFERENCES & FURTHER READING

Jacobs JL, Rigby SE (1999) Minerals in Dairy Pastures in Victoria. Department of Natural Resources and Environment: Warrnambool, Victoria.

CSIRO (2007) Nutrient Requirements of Domesticated Ruminants. (Eds Freer M, Dove H, Nolan JV). CSIRO Publishing: Collingwood, Victoria.

20 COW REQUIREMENTS FOR VITAMINS

Cows need vitamins in small amounts for growth and metabolic functions. There are two types:

- water soluble – vitamin B complex
- fat soluble – vitamins A, C, D, E and K.

To the best of current knowledge, an oversupply of water-soluble vitamins will not harm cows. Any excess is simply excreted in the urine.

Fat-soluble vitamins (vitamins A, D, E and K) are stored in the cow's body, and an oversupply of vitamin A or D can cause poisoning or death.

REQUIREMENTS FOR VITAMIN B COMPLEX

The rumen micro-organisms synthesise all B complex vitamins.

Newborn calves have some stores of the B complex vitamins in their tissues but are primarily dependent on supplies in milk until the intake of solid feed promotes development of the rumen. An active microbial population in the rumen will then, usually, synthesise sufficient of all the B vitamins to meet requirements.

There have been occasional, but inconsistent, responses to supplements of B complex vitamins biotin, folic acid, niacin, pantothenic acid, pyridoxine (B_6) and riboflavin (B_2) in housed animals on high-concentrate diets.

Research at this time has only demonstrated well-established deficiencies for thiamine (B_1) and cyanocobalamin (B_{12}; through its need for dietary cobalt). If cows respond to vitamin B_{12}, it is likely they are deficient in cobalt.

VITAMIN B COMPLEX

Vitamin B_1 thiamine
Vitamin B_2 riboflavin
Vitamin B_3 niacin
Vitamin B_5 pantothenic acid
Vitamin B_6 pyridoxine
Vitamin B_7 biotin
Vitamin B_9 folic acid
Vitamin B_{12} cyanocobalamin

Grazing animals do not require supplementary vitamin A since the hepatic stores can cover for most dietary inadequacies. However, vitamin A deficiency may occur on diets high in cereal grains or cereal straw, or if cattle graze dry pasture for more than six months.

REQUIREMENTS FOR VITAMIN A

Vitamin A, also called retinol, is formed from betacarotene in the diet, particularly in green herbage.

Vitamin A is required by the retina for good eyesight and is needed for tissue and bone formation, growth, milk production and reproduction.

Vitamin A maintains healthy epithelium (the lining of the teat canal), so deficiencies may increase the incidence of mastitis infections.

Any vitamin A surplus to requirements is stored in the liver for up to four months.

REQUIREMENTS FOR VITAMIN C

Ruminant animals synthesise vitamin C (L-ascorbic acid) from glucose, via glucuronic acid and gulonic acid lactone.

Cows do not require a dietary supply of vitamin C.

Vitamin D can be used to alleviate milk fever. However, if calcium and phosphorus levels are adequate in the milker diet, the need for vitamin D is small.

REQUIREMENTS FOR VITAMIN D

Vitamin D is required for calcium and phosphorus absorption and deposition within bone. It stimulates calcium absorption in the small intestine and mobilises calcium stores from the bones.

Vitamin D requirements are provided by most diets, including fresh and dried forages, and by synthesis in skin following exposure to sunlight. Deficiencies are therefore very rare in grazing stock.

Vitamin D toxicity (perhaps due to excessive treatment for milk fever) causes calcification of soft tissues, especially the aorta.

The metabolism of vitamin E and selenium are closely interrelated.

REQUIREMENTS FOR VITAMIN E

Vitamin E (principally α-tocopherol), selenium and vitamin A all help the cow's immune system to function properly.

Both vitamin E and selenium have antioxidant properties that protect biological systems from degradation and may play other key roles in maintaining reproductive health.

A deficiency of either vitamin E or selenium leads to muscular dystrophy (white muscle disease) which produces stiffness, uncoordinated movement and, in severe cases, death. Animals deficient in vitamin E and selenium may have suppressed defences against infectious diseases.

It is not possible to specify a dietary requirement for vitamin K for grazing animals because green forage is a rich source and rumen micro-organisms synthesise large quantities.

REQUIREMENTS FOR VITAMIN K

Vitamin K is actually a general term that describes not a single compound but a series of quinone isomers that exhibit anti-haemorrhagic effects in animals.

In grazing animals, haemorrhage arising from vitamin K deficiency is usually associated with the consumption of vitamin K antagonists, most notably coumarins (such as dicoumarol) that are associated with fungi in conserved fodder that is mouldy. However, the conserved forage species most associated with vitamin K deficiency generally do not feature in Australian grazing systems.

FEED ADDITIVES

Feed additives are neither a requirement nor a guarantee of high productivity or profitability.

Feed additives are components that generally act in a non-nutrient role and can cause shifts in pH and metabolic outcomes.

There are many additives other than minerals and vitamins on the market. Whether any of them are worth using depends on the feeding system in which they are being used and the benefit of the additive relative to its cost.

Before using additives, ask the following questions.

- What response should be expected from this additive?
- What is the cost-benefit?
- What research is there to back claims?

The popularity of additives started in feed-lot environments where high-producing cows are very well-fed and every mouthful of food they consume is a well-mixed, well-balanced entity. Some additives originated from meat-producing industries, and were intended to enhance processes other than the production of milk solids.

BUFFERS

Saliva, produced during chewing, contains sodium bicarbonate and other naturally occurring buffering agents. These agents maintain rumen pH at a level suitable for fibre fermentation. When cows are fed high levels of cereal grains containing starch, rumen fermentation is rapid leading to high concentrations of VFA in the rumen. There is generally much less chewing of grain than of forages and as a consequence much less saliva production.

The subsequent reduction in buffering capacity can lead to a reduction in rumen pH. This in turn leads to a change in the microbial population, with a reduction in fibre-fermenting organisms and an increase in starch-fermenting organisms, which produce lactic acid.

The production of volatile fatty acids, and especially lactic acid, may be greater than the rate at which they can be absorbed or buffered. Lactic acid is stronger than the volatile fatty acids, leading to a rapid reduction in rumen pH and inflammation of the rumen wall and the formation of abscesses (ruminitis).

Pathogenic organisms can pass from the abscesses via the portal blood to the liver, causing liver abscesses, and to the feet, causing laminitis. At low rumen pH, rumen contractions cease and belching stops, leading to bloat and eventually death. This condition, known as acidosis, can be clinical or subclinical, otherwise referred to as lactic acidosis and subacute ruminal acidosis (SARA) respectively.

This sequence of events can be minimised or avoided with feeding strategies that include:

- gradually introducing high-starch feeds to the diet
- feeding a complete mixed diet of forage and concentrates
- feeding smaller amounts of high-starch feeds more often
- processing the high-starch feeds to reduce their rate of fermentation in the rumen
- feeding grains that have different rates of degradation in the rumen: oats and maize are slowest to degrade, crushed wheat is fastest
- adding buffers in the diet
- adding antimicrobial compounds that selectively reduce the organisms responsible for lactic acid production

Buffers used in the dairy industry include sodium bicarbonate and Acid-Buf®.

Alkalinising agents such as magnesium oxide are distinctly different to buffers in that they always cause a pH increase in the rumen and may be harmful if fed in excess.

(AVA 2007)

Note that alkaline substances can be harmful when fed in excess, by interfering with the normal process of acid digestion in the abomasum.

Sodium bicarbonate offers several benefits in milker diets. Not only does it act as a buffer, it also helps meet dietary sodium requirements and provides a positive DCAD for milking cows.

BUFFER RECOMMENDATIONS

Overseas trials with high-concentrate diets have found that buffers can:

- prevent milk fat depression
- prevent decline in rumen pH
- increase the proportion of acetate in the rumen
- improve use of high-energy concentrates in early lactation by preventing the digestive upsets and depression of DM intake often seen with the abrupt introduction of concentrates into the diet.

Note that little work has been done to confirm these findings under Australian conditions with grazing cattle, and much of this research finds little or no benefit.

The usual recommended amount of the buffer sodium bicarbonate is 1.5–2.0% of the grain mixture, or 0.75–1.0% of the total diet.

The amount of sodium bicarbonate included in a diet is almost negligible in comparison to the amount which is produced by the cow each day through chewing and saliva production. Cows fed diets with adequate long fibre produce more than 180 litres of saliva per day, which contains over 2 kgs of sodium bicarbonate.

The use of buffers should, therefore, not replace the requirement for effective dietary fibre.

Warning: sodium bicarbonate has a very high DCAD, so it should not be included in pre-calving transition diets.

Buffers and additives used in medium-high grain diets		
Additive/buffer	**Recommended daily feeding rate**	**Comment**
Sodium bicarbonate	Up to 200–300 grams/cow/day	• Well-known and trusted as a rumen buffer • Works in an optimal pH range of 6.2 to 6.5; buffering ability drops when rumen pH is less than 6.0 • Can be bitter and become unpalatable to stock if more than 4% is fed • Tends to absorb moisture and form clumps which should be sieved out before feeding • Has a high DCAD so unsuitable for pre-calving transition diets
Proprietary products like Acid-Buf®	50–80 grams/cow/day	• Acid-Buf® is manufactured from calcareous marine algae. It acts as a buffer and is also a source of calcium and magnesium. It has a relatively neutral DCAD, making it suitable for use in pre-calving transition diets.
Magnesium oxide	30–45 grams/cow/day (do not exceed 60 grams /cow/day)	• Is not a buffer but a slow-releasing alkalising agent which increases rumen pH • Has a much higher acid-consuming capacity than other buffers and neutralising agents such as sodium bicarbonate • Acid-consuming capacity is dependent on its water solubility which is variable and dependent on particle size • Often used in association with sodium bicarbonate • Source of magnesium to prevent grass tetany
Sodium bentonite	Up to 0.5–1.0 kg/cow/day	• A colloidal, hydrated, aluminium silicate clay • Is not a true buffer but has a high ion exchange and moisture-absorbing capacity
Calcium carbonate (limestone)	Up to 0.4kg/cow/day	• Has limited buffering capacity in the rumen due to its low solubility, despite a high potential to consume acids. However, it may regulate pH in the intestines. • Useful in high grain diets as a source of calcium

The alternative strategy to reduce the incidence of ruminal acidosis associated with high grain feeding is to include antibiotics to reduce the production of lactic acid in the rumen.

Virginiamycin is active against Gram-positive bacteria including Streptococcus bovis and Lactobacillus spp. It is therefore an effective agent for controlling the risk of acidosis in dairy herds and is registered for this purpose. It should be considered in circumstances where other means of controlling acidosis are difficult to manage. It requires veterinary authorisation to use.

The availability of feed additives containing antibiotics such as virginiamycin or tylosin is becoming increasingly limited in response to global concerns about the escalating development of resistance to antibiotics, particularly in human medicine.

YEAST CULTURES AND YEAST METABOLITE ADDITIVES

Much research has been conducted on the topic, and whether live yeasts and yeast metabolites enhance digestion in the rumen and improve rumen fermentation.

Desnoyers et al. (2009) recently undertook a meta-analysis of yeast supplementation in which various strains of Saccharomyces cerevisiae were used. This included 157 experiments and 376 treatments.

Yeast supplementation increased rumen pH (+0.03 on average) and rumen volatile fatty acid concentration (+2.2 mM on average) and had no effect on the acetate-to-propionate ratio.

Yeast supplementation also increased total-tract organic matter digestibility (+0.8% on average), DM intake (+0.44 g/kg LW) and milk yield (+1.2 g/kg LW) and tended to increase milk fat concentration (0.05%) but had no effect on milk protein.

The increase in milk production usually observed when increasing dietary concentrates is often linked to a decrease in milk fat concentration. The positive effect of yeast supplementation on rumen pH increased with the percentage of concentrates in the diet and with DM intake.

As yeast dose rate increased, rumen pH, volatile fatty acid concentration, organic matter digestibility, DM intake and milk yield all increased in a linear fashion.

These results suggest an improvement in rumen fermentation by yeast supplementation.

Whether yeast supplements can be justified, however, depends on the cost of the supplement relative to the benefits obtained, keeping in mind that there was a large amount of variability in the data included in the above analysis.

It is also worth noting that benefits are more likely to be associated with indoor feeding systems than with grazing systems.

ADDITIVES: IONOPHORE RUMEN MODIFIERS

Ionophore rumen modifiers like monensin and lasalocid may improve feed efficiency and prevent or aid in the prevention of digestive and metabolic disturbances caused by erratic feed intake or specific feed problems including acidosis and bloat.

Monensin selectively changes the rumen microbes and modifies rumen total VFAs (propionate % increases) and reduces the lactic acid producing rumen bacteria *Strep. bovis*. Lasalocid acts in a similar way to monensin.

Ionophores can make the digestive process more efficient by increasing energy metabolism through increased production of propionate in the rumen, with a concomitant reduction in methane.

Label claims for ionophores have included increased milk production, improved feed efficiency, control of subclinical and clinical ketosis and control of bloat; and for growing heifers, both major ionophores are labelled as a coccidiostat. However, ionophores may also result in a reduction in milk fat concentration because of the rumen propionate effect, and occasionally milk protein concentration has also declined.

Monensin and lasalocid have been the most-studied ionophores in research and are antibiotics that can change rumen fermentation by reducing Gram-positive bacteria. Monensin is extensively used in beef and dairy feedlots overseas.

Note however, supplementation of grazing dairy cows with ionophores has given variable responses that are difficult to predict.

See Ch 21 Formulating transition diets: Requirements in early dry & pre-calving transition period.

ADDITIVES: ANIONIC SALTS

Anionic salts (sulphates, chlorides) can be used in the 2–3 weeks before calving to help prevent milk fever, but responses are varied depending on potassium and sodium in the diet.

The addition of anionic salts can reduce milk fever risk if combined with feed analysis and a diet balanced for DCAD, P, Mg and Ca.

In practice, the aim is to limit cations, principally potassium and sodium, relative to anions, particularly chlorine and sulphur.

Sources of anions in the diet: comparative aspects

Sources	Comments	References
Mineral sulphates (such as calcium sulphate, magnesium sulphate, ammonium sulphate)	Sulphate salts are more palatable than chloride. Ammonium salts provide non-protein nitrogen (NPN). The NPN can be beneficial on low-protein diets.	
Mineral chlorides (such as calcium chloride, magnesium chloride, ammonium chloride)	Lower DCAD per gm than sulphates. Ammonium salts provide non-protein nitrogen (NPN). The NPN can be beneficial on low-protein diets.	
Hydrochloric acid (such as Anipro®)	Hydrochloric acid is an effective agent to decrease DCAD. Molasses-based, it is used to mask taste and encourage intake.	Goff and Horst (1998)
Hydrochloric acid in a protein meal (such as SoyChlor®)	Hydrochloric acid is an effective agent to decrease DCAD – a safer means to deliver – protein meal provides added benefit. Contains magnesium 2.47%.	Goff and Horst (1998)
Stabilised hydrochloric acid and sulphuric acids in a protein meal (such asBioChlor®)	Hydrochloric acid is an effective agent to decrease DCAD. Sulphur also appears to be an effective and safer means to deliver a protein meal which provides added benefit with specific NPN components to increase rumen efficiency and increase microbial protein production.	De Groot et al (2010) Lean et al (2005)

Source: Lean and DeGaris 2010.

OTHER ADDITIVES

Other additives which may be useful in dairy cows include:

Additive	Comment
Biotin	• Improves hoof health in herds with chronic foot problems. May also improve milk production. • Biotin is a complex B vitamin and is required by ruminants and is synthesised by rumen bacteria. • If diets are high in concentrates, rumen synthesis is reduced due to the acid environment and shift in microbial population.
Protected choline	• A methyl donor which improves fat mobilization, thereby reducing the risk of ketosis and fatty liver and leading to improved milk yield and reproductive performance. Betaine, which is closely related to choline, acts the same. • Most dietary choline is degraded in the rumen. This has prompted the development of rumen-protected choline products which use encapsulation and fat coating.
Chelated (organic) minerals	• Minerals bound to organic compounds such as Se, Zn, Cu and Co are sold on the basis that absorption is enhanced when compared with inorganic forms of the mineral. • Reported to improve immune function, reduce somatic cell counts, increase milk production and fertility and reduce foot disorders. • For some products, improvement in absorption over the inorganic mineral is small, but others can achieve considerably higher levels of absorption.
Niacin	• A complex B vitamin, often used for high-producing cows in negative energy balance, or ketosis-prone cows, through the transition period and into early lactation. • Stimulates rumen protozoa.

Additive	Comment
Probiotics (direct-fed microbials)	• Alive or dead microbes and their metabolites. They may be useful for transition cows and during other periods of stress, to improve nutrient availability and to deal with undesirable organisms and harmful metabolites.
Prebiotics	• Stimulate bacterial growth or reduce bacteria growth that can reduce animal performance. Examples include inulin, oligofructose, yeast cell wall products, mannan oligosaccharide products, butyrate and lactoferrrin.
Enzymes	• Fibre-digesting enzymes are also marketed but if the enzyme is not protected from the rumen microbes the enzyme itself will be digested before it can work. • Recent enzyme products have been protected against digestion but like yeasts results have been variable and the use of enzyme products is difficult to justify, particularly in grazing systems.
Propylene glycol	• A source of glucose that can help to prevent ketosis and reduce fat mobilisation.
Yucca extract	• Can be used to decrease urea-N in plasma and milk by binding ammonia to the glycol-fraction of the *Yucca shidigera* plant, thereby improving N efficiency if protein is in excess in the diet.
Beta-carotene	• Trials demonstrate Improved reproductive performance with higher ovarian levels, increased fibre digestion by rumen microbes, immune response and mastitis control.
Mycotoxin inhibitors	• Clay-based compounds such as bentonite, zeolite and calcium aluminosilicate.

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21

TRANSITION COW NUTRITION

Calving time is very stressful for the dairy cow's body. From four weeks before calving to four weeks after calving (called the transition period), the cow undergoes a series of dramatic metabolic changes. Changes during this period affect the cow's ability to adapt to the challenges of calving, lactation and re-breeding.

Around 80% of cow health problems occur within four weeks of calving including milk fever, grass tetany, ketosis, retained placenta, metritis, ruminal acidosis, displaced abomasum, mastitis and lameness.

Around 80% of disease costs in adult cattle occur in the first four weeks after calving. It is a peak period for involuntary culls and deaths.

The transition period is therefore a period of the cow's lactation cycle when the cow is at great risk.

Calving time is also stressful for herd managers and staff, particularly on farms using seasonal and split-calving systems.

As there are so many tasks to attend to at this time, it is important that management and decision-making is active to stay on the front foot.

Research and experience over the last 25 years about how to manage the transition period has led many Australian dairy farmers to implement very successful transition feeding programs pre-calving. Benefits include:

- dramatic reductions in milk fever and other cow health problems around calving
- improvements in milk production
- improvements in fertility.

Transition feeding does not require a change to the feeding system or milking cows' grain / concentrate feeding rates.

APPROACHES TO TRANSITION FEEDING

There are a number of common approaches to pre-calving transition feeding. Each approach varies in the extent to which it helps the cow deal with the challenges of a successful adaptation to lactation.

The transition feeding approach that best suits a particular farm depends on:

- the farmer's intended grain/concentrate feeding rate during lactation
- the feeding infrastructure and equipment available
- the levels of cow health problems the farmer can cope with (such as the percentage with milk fever)
- the broader health, production and fertility benefits the farmer seeks
- the level of risk that the farmer is prepared to accept from sub-optimal transition nutrition and the threat to cow health, productivity and farm profitability.

Six commonly used approaches to transition feeding

Approach	Pasture / hay only	Pasture / hay + anionic salts in fodder in water	Pasture / hay + grain / concentrate	Pasture / hay + grain / concentrate + DIY anionic salts	Pasture / hay + commercial transition supplement (lead feed)*	Fully integrated transition diet fed as PMR or TMR
Effective terms of						
Rumen adaptation	–	–	✔✔✔✔	✔✔✔✔ – ✔✔✔✔✔	✔✔✔✔✔	✔✔✔✔✔
Positive metab. energy balance	–	–	✔✔✔	✔✔✔✔	✔✔✔✔	✔✔✔✔✔
Positive metab. protein balance	–	–	✔	✔✔	✔✔✔ – ✔✔✔✔	✔✔✔✔✔
Milk fever control	–	✔ – ✔✔	–	✔✔✔	✔✔✔✔✔	✔✔✔✔✔
Other metabolic disease control	–	–	✔✔	✔✔✔✔	✔✔✔✔✔	✔✔✔✔✔
Improved animal health	–	✔✔	✔✔	✔✔✔	✔✔✔ – ✔✔✔✔	✔✔✔✔✔
Improved milk production	–	✔	✔✔	✔✔✔	✔✔✔ – ✔✔✔✔	✔✔✔✔✔
Improved fertility	–	✔	✔✔	✔✔	✔✔✔ – ✔✔✔✔	✔✔✔✔✔
Overall effectiveness	–	✔✔	✔✔	✔✔ – ✔✔✔	✔✔✔ – ✔✔✔✔	✔✔✔✔✔
Comments	Does not address any needs of the transition cow	Does not address rumen adaptation to grain/conc.	Does not address control of macromineral disorders	Possible palatability problems can be difficult to control macro mineral disorders	Can be highly effective strategy if diet is fully integrated	Highly effective strategy

*May not include all the nutritional components necessary to provide a fully integrated transition diet

Source: Lean & DeGaris 2010.

Feeding system	Transition feeding option		
	A	B	C
Low bail – less than 3 kg per day grain to milkers	Pasture/hay + mg/ anionic salts in fodder or drinking water	Pasture/hay + molasses-based commercial transition feed supplement including anionic salts fed in trough or lick drum	

Using just pasture / hay is not recommended.

When pasture dominates it exposes cows to a high risk of milk fever or grass tetany (hypomagnesaemia). When hay dominates it exposes cows to high risks for low production and pregnancy toxaemia.

Farmers who feed less than 3 kg of grain / grain-based concentrate per cow per day to their freshly calved milking cows should consider:

- supplementing transition cows pre-calving with magnesium and anionic salts in fodder or drinking water to help control milk fever and other health disorders related to macro minerals (option A above)
- use of a molasses-based commercial anionic supplement (option B above), which is also a good way of delivering magnesium and anionic salts while also providing additional energy.

Feeding system	Transition feeding option		
	A	B	C
Low bail – more than 3 kg per day grain to milkers			Pasture/hay + grain-based commercial transition feed supplement (lead feed) fed in bail or in springer paddock
Mod-high bail	Pasture/hay + grain-based commercial transition feed supplement (lead feed) fed in bail or in springer paddock		

Farmers who feed more than 3 kg of grain / grain-based concentrate per cow per day to their freshly calved milking herd should consider providing their transition cows with some grain / grain-based concentrate pre-calving to help their rumens to adapt.

Feeding a professionally formulated transition concentrate (lead feed) is the most desirable approach. The lead feed may be fed either in the dairy shed or in the springer paddock. These products include grain, protein supplements, anionic salts, and other components, in combination with pasture / hay.

Note that adding DIY anionic salts to grain is not recommended.

Farmers who use a partial mixed ration (PMR) or hybrid feeding system may also feed a lead feed in the dairy shed or in the springer paddock to their transition cows pre-calving, in combination with pasture / hay.

They also have the option of using their mixer wagon and feed pad to prepare and feed a fully integrated transition cow PMR incorporating grain, protein supplements, magnesium, anionic salts and other components with suitable forages (plus or minus some grazed pasture).

Farmers using a zero-grazing total mixed ration (TMR) are most likely to feed a fully integrated transition cow total mixed ration.

Feeding system	**Transition feeding option**		
	A	B	C
PMR	Pasture/hay + grain-based commercial transition feed supplement (lead feed) fed in bail or in springer paddock	Pasture + forages and grain-based transition feed supplement fed in PMR	
Hybrid	Pasture/hay + grain-based commercial transition feed supplement (lead feed) fed in bail or in springer paddock	Pasture + forages and grain-based transition feed supplement fed in PMR	Forages and grain-based transition feed supplement fed in TMR
TMR	Forages and grain-based transition feed supplement fed in TMR		

Source: Steve Little 2013.

Any improvement in transition feeding management will reap benefits.

Just switching from a high to a lower DCAD hay reduces milk fever risk.

Note though that physical parameters on-farm may make it difficult to move to a fully integrated transition diet.

Farmers may be more willing to direct resources into further improvements in transition management once health and productivity improvements are seen.

Other approaches to transition feeding

Different strategies have been attempted over the years to improve the nutritional management of the dry cow in anticipation of calving and subsequent lactation. However, health and excessive body condition loss remain problems in many herds.

Other approaches used include:

- hydrochloric acid to reduce DCAD
- vitamin D injections pre-calving
- calcium drenches at calving
- high-fibre diets fed throughout the dry period
- reducing or eliminating the dry period.

Some research and advisory groups involved in dairy cow management are now suggesting that an increased focus needs to be directed towards the early dry period in an effort to improve cow health, performance and fertility.

Hydrochloric acid to reduce DCAD

In addition to anionic salts, hydrochloric acid (HCl) has also been used effectively as a source of anions to reduce the DCAD of the transition diet pre-calving.

In liquid form, HCl is dangerous to handle and corrosive to machinery. However, commercial supplements containing HCl have been developed which overcome these problems. These include Anipro®, BioChlor® and SoyChlor®.

Vitamin D injections pre-calving

Vitamin D plays a vital role in the regulation of calcium and regulation of vitamin D production is critical to the success of feeding strategies to control milk fever risk.

There are two ways in which vitamin D may be applied to control milk fever:

- Injection of 1α – cholecalciferol (e.g. Vitamec D3 injection®) between two to eight days before anticipated calving can provide an additional source of vitamin D; the timing of the injection is important to ensure that calcium uptake is not depressed subsequently by premature stimulus of calcium uptake
- it is also possible that active forms of oral vitamin D could stimulate calcium uptake.

Further investigation of vitamin D feeding options is warranted as part of an integrated feeding strategy.

Calcium drenches at calving

Calcium drenches and boluses can aid in the prevention of milk fever if given within 12 hours of calving and continued for several days after calving.

Due to the labour-intensive nature of drenching cows, this strategy is best restricted to cows considered be at high risk of developing milk fever.

With lower intakes during the dry period, it is claimed that post-calving appetites improve and body fat mobilisation is reduced.

The philosophy underpinning the strategy effectively means that any requirement to increase body condition during the dry period is no longer an option.

For further information see:

Beever DE (2006) The impact of controlled nutrition during the dry period on dairy cow health, fertility and performance. *Animal Reproduction Science* 96, 212–226.

Janovick NA, Drackley JK (2010) Prepartum dietary management of energy intake affects postpartum intake and lactational performance of primiparous and multiparous Holstein cows. *Journal of Dairy Science* 93, 3086–3102.

Alternative approach: restricted energy intake

The basis of a strategy described by Beever (2006) is to feed low-energy/high-fibre diets throughout the whole dry period, without distinguishing between the far-off and close-up periods.

This strategy has had considerable on-farm testing in Europe, but direct scientific evidence to support the on-farm anecdotal claims or to better explain the mechanisms involved is only just now starting to emerge (such as Janovick and Drackley [2010]).

The diet specification is:

- 9 MJ of ME/kg DM and 13% crude protein
- a mix comprised of 50% chopped straw and 50% lactation diet, supplied as a total mixed ration
- a target intake of 11–12 kg DM/day for average-sized cows.

The main effect on animal health and associated issues appears to be due to the provision of a relatively low-energy diet so that animals will not overeat. As well as promoting good rumen function, the inclusion of the straw is to limit energy intake.

Although Beever (2006) suggests that this strategy can be applied to grazing dairy cattle, it is really aimed at those with a mixer wagon who intend feeding partial or total mixed rations in early lactation.

If using this approach with cows at pasture, intakes of pasture should not be greater than 2 kg DM/day, especially in the late dry period since greater intakes will compromise calcium metabolism due to increased consumption of potassium, thereby increasing the risk of milk fever.

This strategy seems aimed at overcoming a problem not often seen in Australian dairy herds over the dry period: that of too-high a quality diet, overeating and fat cows and the associated metabolic problems that stem from that.

Alternative approach: reducing or eliminating the dry period

As previously discussed, the post-calving period is associated with an increased risk of metabolic disorders such as fatty liver, ketosis and milk fever. There is therefore some logic in considering a change away from the traditional dry period if there are benefits to be gained to offset losses in milk production.

See Ch 27 for details.

EFFECTIVE PRE-CALVING TRANSITION DIETS

An effective pre-calving transition diet has five key aims:

- meet the cows' growing demand for energy and protein
- maintain dry matter intakes
- adapt the rumen to the post-calving diet
- minimise the risk of milk fever and other health problems
- minimise mobilisation of body tissue and associated lipid mobilisation disorders.

If these five key aims are achieved the benefits are considerable and include:

- the cow is set up for a productive lactation
- almost no clinical cases of milk fever in the herd
- very low incidence of other health problems common soon after calving
- reduced death and culling rates around calving
- improved herd reproductive performance
- less labour and stress spent on sick cows
- improved animal welfare.

Depending on the approach used, a three week pre-calving transition feeding program could cost between $20 and $60 per cow but return a net benefit of up to $200 or more per cow (after additional labour and feed costs are accounted for).

EFFECTIVE TRANSITION DIET – FIVE AIMS

1. MEET DEMAND FOR ENERGY & PROTEIN

Daily requirements for energy and protein increase in the weeks prior to calving as the foetus continues to grow and the bodily systems prepare for the onset of lactation.

Given that intakes reduce in the lead-up to calving while requirements for energy and protein are increasing, it is important to ensure transition cows are fed a good-quality diet.

EXAMPLE

The daily requirements for energy, protein and fibre can be calculated using the methodology and recommendations outlined in Ch 15.

A month before calving, a 550 kg cow requires around 90–100MJ per day and at least 12% CP on a DM basis.

A week after calving, the same cow needs 100–120MJ per day and 14–16% CP on a DM basis and will need a high-quality diet to maintain intakes.

While a moderate quality hay (9–10 MJ ME/kg DM, 13%CP) may be adequate one month from calving, this will fail to meet the cow's needs closer to calving. With her intake restricted, the cow will need a diet of approx. 11 MJ ME/kg dry matter and 14–16% CP to meet requirements.

2. MAINTAIN DRY MATTER INTAKE

Dry matter intake may decline significantly about a week before calving, depending on the quality of the diet. While this can't be prevented, it must be anticipated and managed so it is minimised.

Dry matter intake is likely to be the most critical factor in evaluating the nutritional adequacy of a dry cow diet.

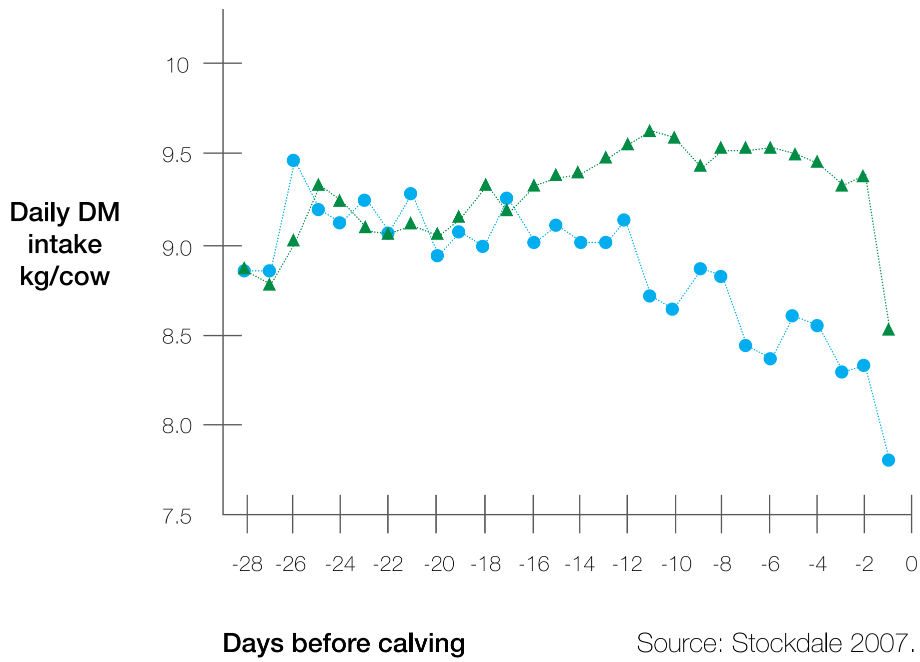
Diets with low digestibility lead to greater and more prolonged declines in intake and will not provide adequate nutrients to meet the cows' increasing requirements.

It is important to minimise the decline in intake around calving for two reasons:

- there is a positive relationship between intake at calving and intake in the early weeks of lactation, and cows with higher intakes in early lactation should be more productive thereafter
- low intake is generally associated with the mobilisation of body tissue, and excessive fat mobilisation often results in metabolic disorders such as ketosis and fatty liver.

If managed well, it is generally only in the last 2–3 days before calving that the greatest decline in dry matter intake occurs, but unfortunately this is when demand is at its greatest. Results of research at Kyabram demonstrate this, as shown in the figure below.

Typical responses in DM intake as calving approaches for cows well-fed with a high-quality total mixed ration (triangles) or poor-quality hay (dots)



Source: Stockdale 2007.

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TRANSITION FEEDING – GUIDING PRINCIPLE

If a particular feed is being fed to freshly calved cows, it should be fed to some level for a full three weeks just prior to calving.

This ensures an adapted rumen right from calving, allowing cows to 'hit the ground running' and not suffer digestive setbacks at the start of their lactation.

As a rough guide, pre-calving transition cows should be fed grain / grain-based concentrate at half the rate fed to the freshly calved milking cows. For example, 3 kg per day if freshly calved cows are fed 6 kg per day.

3. ADAPT THE RUMEN TO THE POST-CALVING DIET

Dry cow diets have a lower energy density than milking cow diets and a lower content of fermentable carbohydrate, even in pasture-dominant feeding systems.

Introducing cows in the pre-calving transition period to highly fermentable feeds such as grain which they will consume after calving allows the rumen to adapt.

Rumen microbial populations take 7–10 days to adapt to a diet change.

Rumen papillae take 3–6 weeks to reach full absorptive capacity.

Adaptation is critical to control the risk of ruminal acidosis (both lactic and subacute ruminal acidosis) and the subsequent declines in fibre digestion and intake.

With the exception of macro mineral nutrition, any feed additives (such as rumen modifiers) included in the diet post-calving should be included in the pre-calving transition diet. But watch out for mineral additives and sodium bicarbonate: these can seriously affect the dietary levels for Ca, Mg, P and DCAD which are so important for reducing milk fever risk.

Mineral requirements for pre-calving transition cows and milking cows are quite different and it is unlikely that a mineral pre-mix designed for one group will be appropriate for the other.

For further information on transition management see: Lean I, DeGaris P (2010) Transition Cow Management, A review for nutritional professionals, veterinarians and farm advisors. Dairy Australia. Search for Dairy Australia Transition cow management.

Picture: Rumen papillae before adaptation (left) and after adaptation (right).

Source: Veterinary Pathology Unit of the University of Melbourne.

See Ch 9 for recommendations on calcium, magnesium, phosphorus and DCAD.

A low blood calcium level at calving leads to these health problems through a reduction in the cow's smooth muscle function and depression of the cow's immune function.

4. MINIMISE RISK OF MILK FEVER & OTHER HEALTH PROBLEMS

Hypocalcaemia or milk fever is caused by inadequate blood calcium available to meet the sudden increase in demand for calcium at the start of lactation. The cost of milk fever is greater than the immediate costs of treatment and stock loss.

Milk fever is a gateway disease which leads to a higher risk of other diseases including mastitis, ketosis, retained placenta, displaced abomasums and uterine prolapse.

Milk fever is also a risk factor for reproductive disorders and an indirect risk factor for increased culling.

Milk fever risk is not solely related to calcium concentrations in feed. It is also influenced by age and breed, condition score and pre-calving transition diet. Time spent on the transition diet is also important.

Age	• Older cows have a higher risk of milk fever than younger cows.
Breed	• Channel Island breeds such as Jerseys are more susceptible than Holsteins.
Body condition	• Research clearly indicates that high body condition score increases risk of milk fever. • Note too that cows CS 6 or above have reduced DM intake pre-calving and take longer to resume high intakes. This leads to greater tissue mobilisation and a higher chance of ketosis and fatty liver.

Pre-calving transition diet	• At the onset of lactation, a cow's requirement for calcium increases by two to four times.
	• At this time the cow's systems need to be able to draw calcium back from bone stores and to optimise absorption of calcium from the diet.
	• Magnesium, phosphorus and DCAD (K, Na, S, Cl) also influence milk fever risk.
	• Recommendations (dry matter basis):
	  • less than 0.6% calcium
	  • greater than 0.45% magnesium
	  • less than 0.4% phosphorus
	  • less than 80 mEq / kg DCAD.

Time cows are exposed to transition diet	• Recent Australian research supports the recommendation that the optimum time on the pre-calving transition diet is around three weeks. • To achieve this it is essential to predict calving dates very accurately. This means early and accurate pregnancy diagnosis is critical.

Cows in high body condition scores at calving (BCS 6 or above) have severely depressed appetites immediately before and after calving and are at high risk of developing ketosis and fatty liver.

For information and tools to assist in measuring and managing herd body condition profiles, visit www.dairyaustralia.com.au/BCS.

5. MINIMISE MOBILISATION OF BODY TISSUE

During periods of poor-quality feed intake or a lack of feed, ruminants can mobilise body tissue reserves of protein or fats in support of the foetus and milk production.

Increased tissue mobilisation increases the flow of free fatty acids to the liver for oxidation. This increases the need to export some of these back to peripheral tissues as ketones.

The liver may not be able to re-export sufficient of these and fat is accumulated. This leads to:

- poor liver function
- reduced ability of the liver to produce glucose
- fatty liver and ketosis.

This is a high risk in fat cows.

Providing a high-quality diet during the transition period helps maintain DM intakes.

The aim is to provide the daily requirements for energy and protein within the limited intakes achievable in the transition period. This minimises tissue mobilisation.

SUCCESSFUL TRANSITION – FOUR KEYS

1. Accurate due calving dates

It is only possible to feed for the optimal period of three weeks with accurate due calving dates.

Accurate conception and due calving dates can be obtained from early rectal pregnancy testing by a skilled operator between 5–15 weeks of gestation.

2. A nutritionally sound, low milk fever risk transition diet

All varieties of pasture, hay and silage vary widely in their mineral specifications, so typical values provided in reference books can be very misleading.

Don't leave it to chance: analyse representative samples of all transition forages. Use an accredited feed lab to check nutritional parameters before using the feed.

If buying hay / silage for feeding to their transition cows pre-calving, farmers should aim to buy a single consignment from a one source and dedicate it to their transition cows.

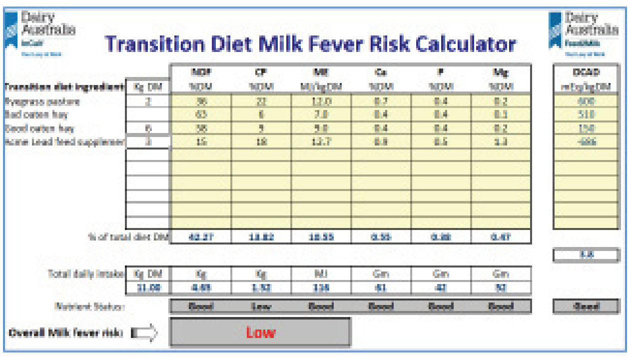
Due diligence is also required with lead feed supplements to be used. If an approximate analysis for the above nutritional parameters is not provided by the manufacturer on the bag tag or product brochure, it shouldn't be used.

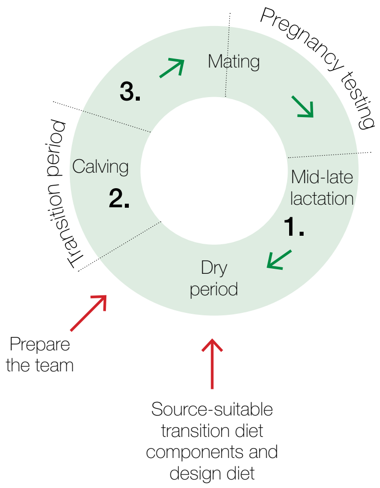
Calculating the milk fever risk (low, moderate or high) of a pre-calving transition diet is difficult to do by hand without making errors. However, Dairy Australia's *Transition Diet Milk Fever Risk Calculator* makes it quite easy.

When testing feeds to assess their suitability in transition diets, be sure to:

- **collect a truly representative sample of each feed**
- **request a special transition feed analysis package which includes Ca, P, Mg and DCAD analysed using wet chemistry methods: a standard NIR-based feed analysis won't provide the information needed.**

Search for *Dairy Australia: Transition Diet Milk Fever Risk Calculator.*





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Advisers can help farmers clearly define new roles and responsibilities, consider the new skills and procedures involved, write operating procedures, and even assist with staff training.

For a checklist of the many factors which need to be considered for effective transition cow management, search for *Dairy Australia Transition cow management*.

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3. A well-prepared farm team

A transition feeding program introduces new tasks and different work routines at what is already a very busy time of the year for seasonal and split calving herds.

Is the system for grouping cows based on due calving date clear?

Are you confident that everyone involved can correctly measure ingredients?

Is everyone trained to observe feeding behaviour and manage feed troughs for minimal wastage?

Too often, these three key things are not adequately addressed, or left to the last minute. They need to be set up well before the transition period commences.

4. Good control over cows' daily transition feed intakes

Every effort must be made to ensure that each animal in the transition group gets unrestricted access to each component of the transition diet and eats the quantity intended per day, consistently from day to day.

At least 75 cm of trough space per animal should be provided if grain / transition supplement is fed.

Adequate access to hay and silage must also be provided.

If pasture is fed, the area provided per day must be carefully calculated based on the pasture mass available and the number of cows in the transition group.

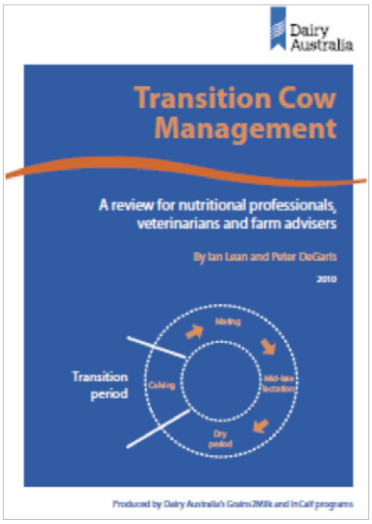
MANAGING THE POST-CALVING TRANSITION PERIOD

While the focus of transition management of the dairy cow tends to be on the pre-calving transition period, the transition period extends to the first four weeks of lactation, during which the cow's udder continues to develop, her appetite and immune function recover and her reproductive activity resumes.

All the principles of sound nutrition that are important in the pre-calving transition period are equally important in the post-calving transition period:

- ongoing adaptation of the rumen to highly fermentable feeds, critical to controlling the risk of acidosis
- minimising the depth and length of negative energy and protein balance, and therefore body condition loss in early lactation
- continuing to meet the cow's daily calcium, phosphorus, magnesium, micro-mineral and vitamin requirements.

See the table on page 9.13 for nutrient recommendations for freshly calved cows.



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Search for Dairy Australia Transition cow management.

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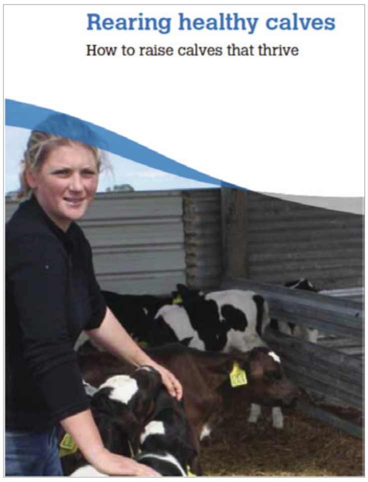
22

CALF AND HEIFER NUTRITION REQUIREMENTS

Calves that are poorly managed from birth are disadvantaged for their entire life. Even if they are well-fed after mating, their ultimate mature size is restricted and if they do put on extra weight, it tends to be as fat.

The essence of good calf rearing depends on two major nutritional factors:

- an adequate intake of high-quality colostrum within the first day of life
- feeding management that encourages early rumen development: the system should rear the rumen rather than the calf.



Search for Dairy Australia Rearing healthy calves.

COLOSTRUM IS ESSENTIAL FOR ALL CALVES

Newborn calves are very susceptible to disease. Before they can develop their own immunity, they are entirely dependent on the antibodies contained in their dam's milk.

Colostrum has five protective constituents that offer the calf protection until it can develop antibodies of its own at around six weeks:

- antibodies or immunoglobulins – these prevent and fight disease
- white blood cells – these play a role in disease control but only last around 24 hours
- growth factors – these promote development of the stomach and intestines and other body tissue
- antimicrobial factors – thought to operate in the intestines and play a role in disease prevention
- nutrients – colostrum is a rich source of protein, fat, vitamins and mineral.

It is critical to get adequate quantities of good-quality colostrum into all calves as soon as possible after birth to achieve successful passive transfer of antibody IgG. This colostrum should ideally be sourced from the calf's dam.

Good-quality colostrum has an IgG concentration of greater than 50mg/ml. Use a refractometer to check.

Providing calves with the right amount of good-quality colostrum at the right time gets calves off to a good start.

The minimum recommendation is at least 2 litres in the first 12 hours after birth and at least another 2 litres within the next 12 hours. However, greater volumes and more frequent feedings will increase the likelihood of transfer of immunity.

The next step is to manage calves' transition from milk drinkers to eaters.

Liquid feed – milk or milk replacers – provides the main source of nutrients for the newborn calf.

The rumen develops as the calf grows and in response to feed it encounters – grains/concentrate, fibre and pasture.

Careful feeding management gets calves off to a healthy start and ensures a productive future.

If high levels of calf disease are found, it might be worth testing for failure of passive transfer. Vets can provide this testing.

Results with a value of 55 mg per ml of serum (or above) indicate that successful passive transfer has occurred.

If 20% or more of the tested calves are below 55mg/ml then a review of the colostrum management system is needed.

For more detailed **recommendations on colostrum quality, the timing and quantity** of colostrum feeding, search for *Dairy Australia Rearing healthy calves manual.*

Understanding calf milk replacers

Modern milk replacers can be used to successfully rear healthy calves. Before deciding to use a milk replacer you should weigh up the advantages and disadvantages for your calf rearing system. Ease of handling with automated calf feeding systems, high milk prices and minimal waste milk are reasons why they are favoured on some farms. Only high quality reputable products should be used otherwise health problems and poor growth rates may result.

Advantages

- Consistency of product (when mixed correctly) – less risk of digestive upsets and scours
- Can be stored and handled more easily than liquid foods
- Easily fortified with additional vitamin, minerals and medicines if necessary
- A potential cost benefit over saleable whole milk
- Less risk of disease transfer from cow to calf
- Well suited to automated calf feeding systems

Composition of milk replacers

Clot-forming or non clot-forming

Traditional milk replacers are made from downgraded skim milk powders, and are digested like whole milk, forming a clot in the abomasum. Early products varied in quality - mostly due to the processing of casein - and sometimes caused scouring. The majority of milk replacers sold in Australia still contain significant percentages of skim milk powder.

Whey proteins are digested in the small intestine and do not form a clot in the abomasum. The increasing value of casein and improvements in filtration and purification methods have seen whey based milk replacers that can produce average daily weight gains and performance comparable to casein based products.

Modern whey based milk replacers lead the market in the US and Europe and are gaining share in New Zealand.

Protein

A newborn calf is better able to digest milk protein than plant protein sources. Milk proteins are the best sources for growth and development of calves and should provide most of the protein in a milk replacer. With increasing age,

Search for *Dairy Australia Fact Sheet: Understanding calf milk replacers.* This outlines the components and benefits of different formulations.

MANAGING LIQUID FEEDING

With their undeveloped digestive tract, calves require the highest quality and the most easily digestible source of nutrients: whole milk or milk replacers.

It is generally more economical to use milk surpluses first as often milk replacers are expensive.

The recommended volume of milk/milk replacer is 10% of a calf's bodyweight daily – for example, a 45 kg calf would require around 4.5 litres per day.

Once or twice a day feeding routines produce the same outcomes.

Automated systems have been found to reduce nutritional or non-infectious scours.

Liquid feed is best provided at consistent temperature. Avoid feeding warm milk at one feed, cool the next.

Teat and bucket feeding can both be successful: one method is not superior to the other.

While there is no single best way to manage liquid feeding, be aware that recommendations do change in light of new research.

ADVISOR ALERT

There is currently interest in increasing the amount of energy and protein consumed by the milk-fed calf to achieve their enormous genetic potential for growth.

Accelerated growth formulas (with a similar protein concentration to whole milk but a lower fat concentration) have been shown in recent US calf feeding studies to increase lean growth and feed efficiency, reduce health problems and increase milk yield in the first lactation and subsequent lactations.

Note: In recent years, there has been increasing awareness of the importance of increasing the amount of milk fed to the calf.

If left on its mother, a calf will suckle about 10 times per day and consume an average of 20% of its body weight per day in milk. This is twice as much milk as a calf would normally receive on a traditional program on most dairy farms.

FEEDING FOR RUMEN DEVELOPMENT

The ability to wean a calf is dependent on having a developed rumen that functions well.

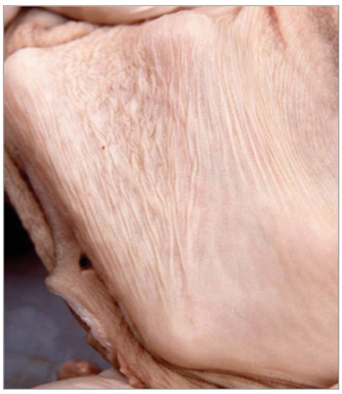
Rumen development occurs through the digestion or fermentation of feeds by rumen microbes. The end products are volatile fatty acids.

For many years, producers have fed fibrous feeds like straw to calves to promote ruminal development. The common reason was to give the calf the 'scratch' needed to start the workings of the rumen, but in fact this concept of scratch is largely a myth.

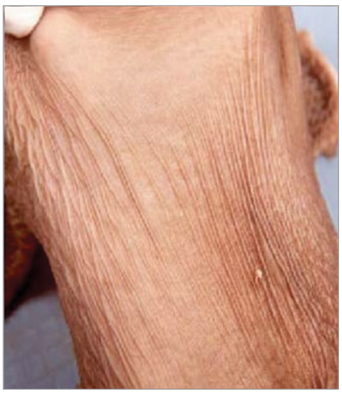
The development of the rumen is driven by the production of the volatile fatty acids propionate and butyrate.

Concentrates are digested to propionate and butyrate.

These volatile fatty acids stimulate the growth of the rumen papillae. The digestion of milk and forages does not provide the right end products to do this.



Diet: milk only
6 weeks



Diet: milk & hay
6 weeks

Diet: milk & grain
6 weeks

Source: Penn State University, USA.

RECOMMENDATIONS: EARLY SOLID DIET

Calves should be encouraged to eat solid feeds from about three days of age.

A small amount of a good-quality starter feed should be offered fresh every day, with free access to drinking water.

Note that no hay or straw is necessary until at least two weeks after weaning.

Calf starters are available in three different forms: textured, pelleted or meal.

Daily calf starter feed intake should be monitored closely. Early consumption of large amounts of calf starter should not be taken as a sign of good rumen development. It is in fact an indication that the young calf is not receiving enough nutrients through its milk to satisfy its nutritional requirements for maintenance and growth and is seeking other sources of nutrients to fulfil these requirements.

Energy	• Supplements for calves from birth to weaning should have adequate energy supplied from a grain base. • Values of 13-14 MJ ME/kg dry matter are acceptable. • Grain-based products produce propionate and butyrate, the breakdown chemicals that encourage the growth of rumen papillae.
Protein	• Calf starter and grower feeds should contain at least 18% and 16% crude protein (CP) respectively on an as-fed basis. • There is increasing interest in calf starter and grower feeds containing higher levels of protein (for example 22% and 20% respectively on an as-fed basis) as these may give superior results if they contain high-quality protein sources.
Additives	• Some concentrates contain additives which aid rumen function and feed conversion and may promote optimal growth rates. However, they are not essential. • The addition of coccidiostats may be of value where coccidiosis is considered a risk.
Vitamin premixes	• Prior to the development of the rumen, calves are not able to manufacture any of the B group of vitamins and so addition of these may be of some benefit.
Probiotics	• Confirm there is a scientific benefit prior to using probiotics.

Source: Rearing healthy calves, Dairy Australia 2012.

THE CHALLENGE OF WEANING

Weaning is a challenging time for a calf, which must cope with the stresses of a change in diet, housing and husbandry practices, competition from other calves and exposure to more pathogens.

Weaning may be done abruptly or gradually.

Calves should be weaned by liveweight, not age.

The process of transitioning calves from a total milk or milk plus some dry feed diet to a 100% dry feed diet is much more complicated than many people think.

There are two very important factors that must be considered when designing a successful transition management and nutrition program for the dairy calf:

- the ability of the calf to consume enough high-quality starter to supply its nutrient requirements prior to weaning,
- adequate rumen development.

Both of these factors are often ignored when weaning calves based on age only.

For further information see Corbett RB (2013) 'Transition management of the dairy calf'. Robert Corbett Article: Transition management of the dairy calf.

Indications for weaning

For the calf to survive and thrive, weaning should only occur when there is evidence that adequate rumen development has occurred.

The best indicator for weaning is consistent intake of concentrate.

Monitoring concentrate consumption is essential if early weaning is undertaken.

Breed	Rate of concentrate consumption
Holsteins	0.75 to 1 kg per day
Jerseys	0.5 to 0.75 kg per day

There should be evidence that the calf has maintained this level of consumption for at least three consecutive days.

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NUTRITION FOR WEANED HEIFERS

The aim is to produce a heifer that is 85% of mature live weight by first calving.

Replacement heifers are expensive to rear to first calving. After considering the cost of producing the calf, its rearing to weaning, feed costs to first calving plus mating and health care, most producers will pay out lots of money before a heifer starts paying her way. The economic benefits from higher milk production, better fertility and lower culling rates can often justify the additional costs of better rearing systems.

Dairy heifers need to be well-fed between weaning and first calving. If underfed, heifers will use feed for growth rather than for milk.

Puberty occurs in dairy heifers at 35–45% of mature weight.

Conception can occur at 45–50% of mature weight.

Increased production benefits of well-fed heifers extend well beyond first lactation.

Large heifers:	Small heifers:
• cycle sooner and get in calf earlier the first time • get back in calf sooner for their second lactation • need less help calving • produce more milk in their first lactation and over their life in the herd • cope better with herd competition.	• experience first cycle later and have lower conception rates – this disrupts calving patterns • greater difficulty getting back into calf during their first lactation • produce less milk in first and subsequent lactation • compete poorly with older, bigger cows for feed.

In the first six months post-weaning, growing heifers should be fed concentrates that are formulated specifically for them rather than just feeding them the same concentrates as those provided for the milking herd.

Tasmanian research found that increasing calving live weights from 360 kg to 460 kg had the following effect on milk production:

- first lactation milk production rose by 400 litres
- second lactation an extra 830 litres of milk/100 kg live weight
- third lactation extra 840 litres of milk/100 kg live weight.

Heavier heifers are less likely to be culled for poor milk yield or poor fertility during their first lactation.

The InCalf project showed a strong, generally linear, increase in six-week in-calf rates for Holstein-Friesian heifers in their first lactation with increasing pre-calving live weight up to about 540 kg. Thus, total herd costs can be greatly increased by this high rate of wastage.

Producers should aim to lose no more than 20% of their replacement heifers between weaning and their second lactation.

Over-feeding 6–12 months post-weaning

For many years it was believed that excessive growth rates during the critical 6–12 month period may increase the deposition of fatty tissue in the udder and reduce lifetime productivity. However, more recent research has found that:

- there are two types of tissue in the udder (mammary parenchyma and the mammary fat pad) which respond differently to nutrition
- pre-pubertal udder development is not directly correlated with first lactation milk yield.

Heifers should be fed a diet well-balanced in energy and protein that allows good frame development without excessive conditioning. Exercise also important during this phase.

Note that excessive growth rates and conditioning are unlikely to be a problem in heifers fed a pasture-based diet, particularly in spring-calving herds. The 6–12 month critical period coincides with autumn and winter, a time of seasonal pasture shortages.

For further information and tools on heifer management, search *Dairy Australia Animal management.*

TARGETS WEIGHTS FOR HEIFERS

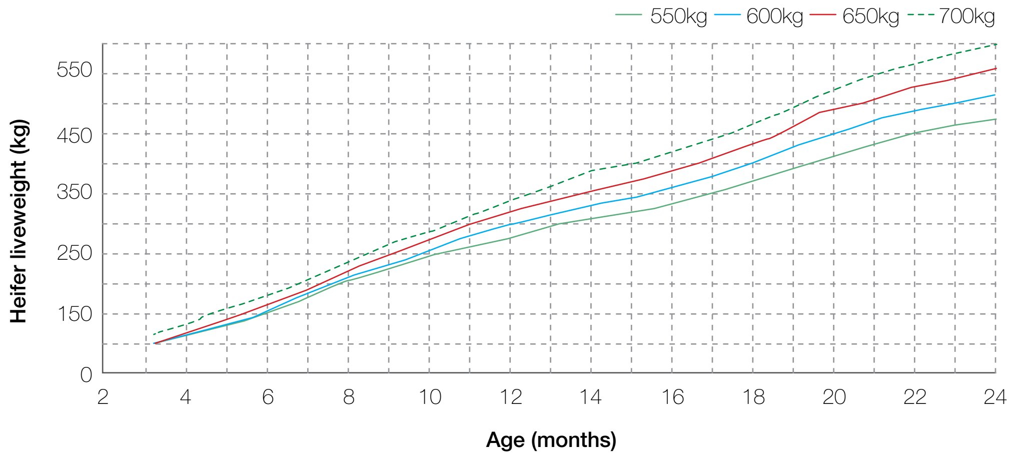
Monitoring heifer weights is critical to achieve target live weights.

Live weight at first calving defines the milk production that animals might achieve at maturity.

Due to the importance of attaining growth targets, cattle scales are useful. Scales with digital readouts can be purchased or hired from herd improvement organisations.

Autumn-born Holstein-Friesian heifers

Rearing autumn-born Holstein-Friesian heifers to reach 85% of desired mature cow liveweights of 550, 600, 650 or 700* kg pre-calving

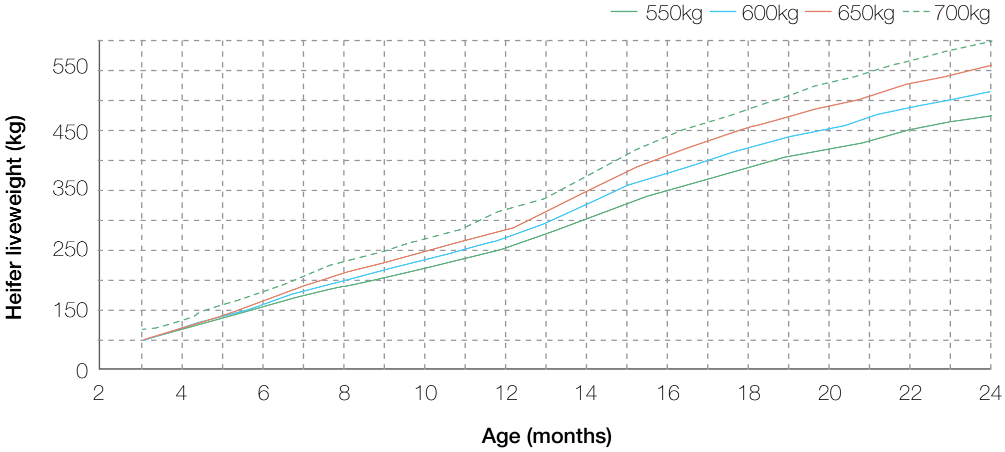


The weight-for-age targets in the growth curves are based on extensive Heiferlink data and incorporate seasonal variations in rates of daily liveweight gain typical of well-reared heifers on farms in southern Australia.

*The growth curve for 700 kg mature cow liveweight should only be considered in large farmed herds on high-feed input management systems.

Spring-born Holstein-Friesian heifers

Rearing spring-born Holstein-Friesian heifers to reach 85% of desired mature cow liveweights of 550, 600, 650 or 700* kg pre-calving



The weight-for-age targets in the growth curves are based on extensive Heiferlink data and incorporate seasonal variations in rates of daily liveweight gain typical of well-reared heifers on farms in southern Australia.

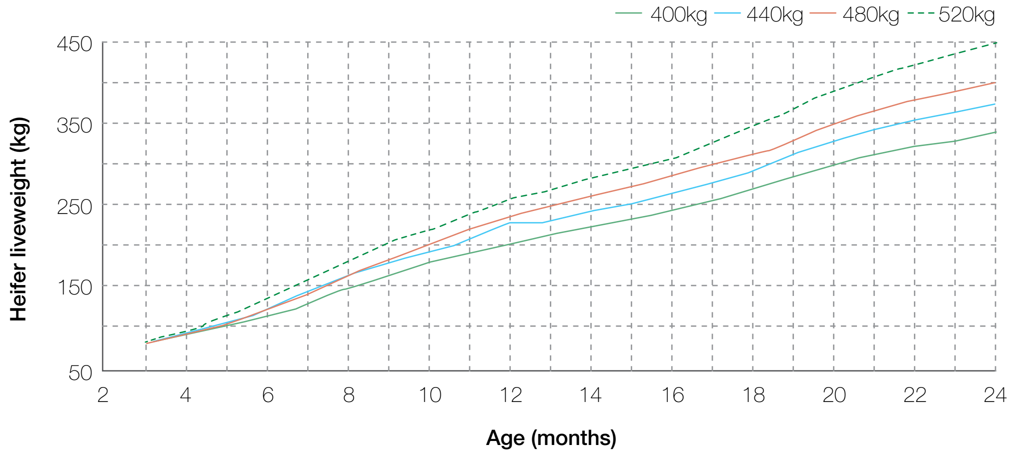
*The growth curve for 700 kg mature cow liveweight should only be considered in large farmed herds on high-feed input management systems.

22

For further information and tools on heifer management, search for *Dairy Australia Heifer Management.*

Autumn-born Jersey heifers

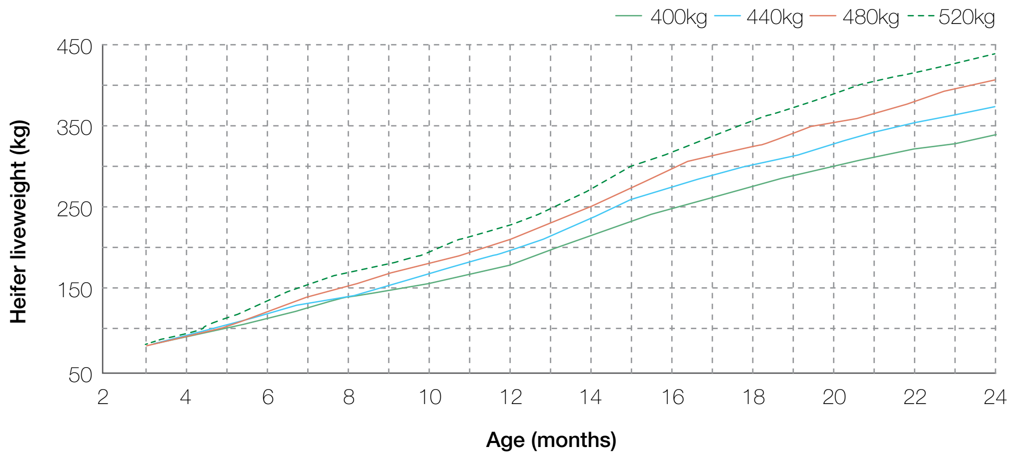
Rearing autumn-born Jersey heifers to reach 85% of desired mature cow liveweights of 400, 440, 480 or 520* kg pre-calving



The weight-for-age targets in the growth curves are based on extensive Heiferlink data and incorporate seasonal variations in rates of daily liveweight gain typical of well-reared heifers on farms in southern Australia.

Spring-born Jersey heifers

Rearing spring-born Jersey heifers to reach 85% of desired mature cow liveweights of 400, 440, 480 or 520* kg pre-calving



The weight-for-age targets in the growth curves are based on extensive Heiferlink data and incorporate seasonal variations in rates of daily liveweight gain typical of well-reared heifers on farms in southern Australia.

*The growth curve for 520 kg mature cow liveweight should only be considered in large farmed herds on high-feed input management systems.

Wither height sticks or chest girth tapes are less accurate for older and pregnant cattle. Chest girth tapes tend to overestimate live weights of heifers heavier than 200 kg.

Wither height sticks or chest girth tapes are alternatives to scales. Their accuracy depends on correct use. Have the animal standing square with its head up and the tape firm (not too tight or too loose).

Wither height is a measure of bone growth and frame size in heifers. Frame size can influence the ease of calving and appetite of milking cows.

Stage	Holsteins	Jerseys
At mating	122 – 132 cm	112 – 120 cm
At calving	130 – 140 cm	120 – 130 cm

Weigh heifers every three months. Consider drafting out those that are more than 10% below the applicable weight-for-age target for preferential feeding.

The difference in energy requirements between penned and grazing animals is the inclusion of E_{graze} which accounts for the additional energy needed by animals at pasture. As detailed for mature animals this is assumed to be 10% of the ME for maintenance.

E_{graze}

The energy associated with grazing is included either as 10% of ME_m for grazing cows or zero for housed cows.

HEIFER ENERGY REQUIREMENTS

Heifers need high-quality supplements for at least six months of the year, whenever pasture availability or quality is low.

Use high-quality supplements containing at least 11.5 MJ ME/kg dry matter.

Equation 1 below is used to calculate ME requirements for the maintenance (ME_m) of heifers. Maintenance requirements are calculated using the equation for mature animals. Added to this is the energy needed for growth and fattening.

k_g in young, growing animals like heifers varies directly with the ME concentration of the diet and is calculated from the following equation:

k_g = 0.043 x ME of the diet.

Equation 1 Metabolisable energy requirements for the maintenance (ME_m) of dairy cows

ME_m (MJ/day) = K.S.M.(0.28W$^{0.75}$.exp(-0.03A))/k_m + 0.1ME_p

K	= 1.4 for *Bos taurus* animals
S	= 1.0 for females and 1.15 for bulls
M	= 1 + (0.23 x proportion of digestible energy from milk)
W	= live weight (kg)
A	= age in years, with a maximum value of 6.0.
k_m	= net efficiency of use of ME for maintenance k_m = (0.02 x average ME of diet) + 0.5
ME_p	ME_p = amount of dietary ME (MJ) being used directly for production

See Look up tables 1 a-e:
Worked example – see Appendix Calculating heifer energy requirements plus worked example

The table below shows the energy requirements for maintenance and growth of heifers growing at different rates at various live weights.

Note that for 500 kg heifers, there is also likely to be a foetus growing at about 0.4 kg/day. There would need to be an additional energy contribution to cover this.

Diets with different ME concentrations will result in different efficiencies of use of ME for growth (kg), so energy requirements will also vary.

Energy requirements for growing heifers that are grazing (dietary ME = 10 MJ/kg DM) SRW 550 kg

Live weight			
kg	Energy requirement (MJ/day)		
	Growth rate (kg/day)		
	0.5	0.6	0.7
100	34	37	40
200	53	57	61
300	71	77	82
400	85	91	97
500	94	100	105

Source: CSIRO 2007.

ADVISER ALERT

US stockfeed companies are now manufacturing calf starter and grower feeds with much higher protein levels than those recommended here. This is further to studies which have shown that such diets help increase heifer growth rates before and after weaning.

HEIFER PROTEIN REQUIREMENTS

Growing heifers require a consistent source of protein for optimum bone and muscle growth.

Protein requirements for growing heifers that are grazing *	
Live weight	**Crude protein requirement %**
100	17
200	16
300	15
400	13
500	13
Source: CSIRO 2007.	

*See Corbett R (2013) InCalf Symposium, Dairy Australia for further discussion.

As with mature cows, heifer replacements need fibre to maintain effective rumen function.

Heifers need energy for maintenance and growth but because of bone and muscle growth, they need more protein than a non-lactating cow.

Critical times for feeding supplements are post-weaning and when there is a shortage of quality pasture. This is usually for at least six months of the year in most Australian dairy regions.

FEEDING TO ACHIEVE TARGET WEIGHTS

After weaning, good-quality pasture should be an integral part of a heifer's diet with hay, silage and concentrates used to overcome pasture shortages and to ensure that animals achieve their desirable target live weights.

The challenge at this stage is that heifers' physical capacity is limited and they often cannot consume enough dry matter from pasture or hay to meet their nutrient requirements for rapid growth.

Pasture and forages must contain at least 10 MJ/kg DM to enable heifer requirements for maintenance and growth to be met.

Pasture must be at least 11 MJ/kg DM if used as the sole feed for heifers less than 12 months of age.

Many types of concentrates can be fed to supplement grazing heifers.

The cheapest and easiest grain to feed is whole oats as it does not need to be rolled before feeding. A rule of thumb for feeding whole oats is 1% of live weight when heifer growth rates fall below 0.5 kg/day.

The important thing is to assess live weight, and therefore growth rate, regularly.

If fully weaned calves weigh 100 kg by 12 weeks of age, and assuming pasture quality is sufficient for three months of the year to promote growth of at least 0.7 kg/day without supplements, then 2–3 kg/day of concentrates can be fed to fill feed gaps during the remaining 15 months through to calving.

Until heifers reach 200 kg in weight, they are not able to maintain the growth rates needed to reach target weights on diets of either average quality pasture or good-quality hay.

The best way to help heifers below the target weight to catch up is to separate them into a separate group and preferentially feed. This reduces the competition for feed and enables you to direct supplements to the heifers that need it most.

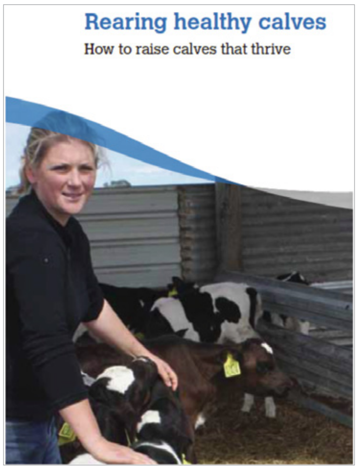
Grazing heifers with the main herd of dry cows during the heifers' last months of pregnancy can accustom them to the competitive conditions with which they will have to cope during lactation. Hand feeding heifers for a few weeks before calving will provide extra feed to build up body reserves as well as to get them used to being handled.

ADVISER ALERT

Although pasture quality and allocation should allow for continuous growth, uniform growth may not always be achievable with fluctuating pasture availability.

Yearling heifers have the ability for compensatory gain following periods of mild undernutrition, and this might happen during the spring flush of pasture growth following feed shortages in the preceding winter.

However, heifers should not be allowed to lose weight or to grow very slowly for longer than two weeks.



Search for *Dairy Australia Rearing healthy calves.*

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CALCULATING HEIFER ENERGY REQUIREMENTS

ENERGY FOR MAINTENANCE

The following equation is used to calculate ME requirements for the maintenance (ME_m) of heifers. Maintenance requirements are calculated using the equation for mature animals. Added to this is the energy needed for growth and fattening.

k_g in young, growing animals like heifers varies directly with the ME concentration of the diet, and is calculated from the following equation:

k_g = 0.043 x ME of the diet.

Equation ME_m **ME requirements for the maintenance (ME_m) of dairy cows**	
ME_m (MJ/day) = K.S.M.(0.28$W^{0.75}$.exp(-0.03A))/k_m + 0.1ME_p	
K	= 1.4 for *Bos taurus* animals
S	= 1.0 for females and 1.15 for bulls
M	= 1 + (0.23 x proportion of digestible energy from milk)
W	= live weight (kg)
A	= age in years, with a maximum value of 6.0.
k_m	= net efficiency of use of ME for maintenance k_m = (0.02 x average ME of diet) + 0.5
ME_p	ME_p = amount of dietary ME (MJ) being used directly for production
Worked example – see Appendix Calculating heifer energy requirements plus worked example See Look-up tables 1 a-e:	

EXAMPLE HEIFER

Breed: **Holstein**

Age: **15 months**

Current weight: **340 kg**

Target calving weight: **510 kg**

Target growth rate: **0.7 kg per day**

Mature weight – standard reference weight (SRW): **600 kg**

Estimated diet quality: **11 MJ ME/kg DM**

Other: **Grazing, no daily requirement for activity as not yet commuting to the dairy, not yet pregnant.**

Equation ME_m ME requirements for the maintenance (ME_m) of dairy cows		Worked example: heifer
ME_m (MJ/day) = K.S.M.(0.28$W^{0.75}$.exp(-0.03A))/k_m + 0.1ME_p		
K	= 1.4 for *Bos taurus* animals	K = 1.4
S	= 1.0 for females and 1.15 for bulls	S = 1
M	= 1 + (0.23 x proportion of digestible energy from milk)	M = 1
W	= live weight (kg)	W = 340
A	= age in years, with a maximum value of 6.0	A = 1.4
k_m	= net efficiency of use of ME for maintenance k_m = (0.02 x average ME of diet) + 0.5	k_m = (0.02 x 11) + 0.5 = 0.72
ME_p	ME_p = amount of dietary ME (MJ) being used directly for production	ME_p = 0
ME_m = K x S x M x (0.28 x $W^{0.75}$ x exp(-0.03 x A)) ÷ k_m + (0.1 x ME_p) ME_m = 1.4 x 1 x 1x (0.28 x $340^{0.75}$ x exp(-0.03 x 1.4)) ÷ 0.72 + (0.1 x 0) ME_m = 41 MJ E_{graze} = 10% of ME_m E_{graze} = 4 MJ		
Total daily requirement for maintenance = 45 MJ ME (including E_{graze})		

ENERGY FOR ACTIVITY

This may be applicable if young stock are being moved daily (for example, following the milking herd in rotation). If young stock are being moved irregularly, this calculation is not needed. See Ch 16 for an example of how to calculate daily requirements for activity.

EXAMPLE HEIFER

Breed: Holstein

Age: 15 months

Current weight: 340 kg

Target calving weight: 510 kg

Target growth rate: 0.7 kg per day

Mature weight – standard reference weight (SRW): 600 kg

Estimated diet quality: 11 MJ ME/kg DM

Other: Grazing, no daily requirement for activity as not yet commuting to the dairy, not yet pregnant.

Equation activity
Energy used when walking to and from the dairy each day

Horizontal activity (HA) = (0.0026 x distance x W)/km

Vertical activity (VA) = (0.028 x (distance x vert.) x W)/km

W	= Live weight Horizontal and vertical components based on live weight (W)
HA	= the energy cost associated with horizontal activity
VA	= the energy cost associated with vertical activity
walking (horizontal component)	= 2.6 kJ/kilometre per kg W
walking (vertical component)	= 28 kJ/kilometre per kg W
Distance	= the distance (kilometres) walked per day when away from the paddock
vert.	accounts for variation in the gradation of terrain and is defined by the kilometre vertical climb per kilometre walked (flat: 0.001; undulating: 0.04; steep: 0.1)
k_m	= the efficiency of use of ME for maintenance

See Look-up table 2

ENERGY FOR PREGNANCY

The same equation as for adult stock is applicable here.

See Ch 16 for an example of how to calculate daily requirements for pregnancy.

EXAMPLE HEIFER

Breed: Holstein

Age: 15 months

Current weight: 340 kg

Target calving weight: 510 kg

Target growth rate: 0.7 kg per day

Mature weight – standard reference weight (SRW): 600 kg

Estimated diet quality: 11 MJ ME/kg DM

Other: Grazing, no daily requirement for activity as not yet commuting to the dairy, not yet pregnant.

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Equation $ME_{pregnancy}$ ME requirement for pregnancy $ME_{pregnancy}$	
$ME_{pregnancy}$ = 349.16*0.0000576*EXP(-0.0000576*t)*SBW*EXP(349.22-349.16*EXP(-0.0000576*t))/k_c	
SBW	= scaled birth weight, which is the ratio of expected birth weight of the foetus to a standard 40 kg Holstein-Friesian calf
t	= time (days) after conception
k_c	= the efficiency of use of ME for conceptus energy gain (k_c = 0.133)
See Look-up table 3	

ENERGY FOR GROWTH

EXAMPLE HEIFER

Breed: Holstein

Age: 15 months

Current weight: 340 kg

Target calving weight:
510 kg

Target growth rate:
0.7 kg per day

Mature weight – standard reference weight (SRW):
600 kg

Estimated diet quality:
11 MJ ME/kg DM

Other: Grazing, no daily requirement for activity as not yet commuting to the dairy, not yet pregnant.

Equation ME_{growth}
Energy used for growth

The process for estimating the ME requirements for growth in heifers using changes in condition score.

SRW	Standard reference weight (what the heifer will weigh when mature and at BCS 5)
LW	Current live weight
Z	= LW÷ SRW
EBG	= Empty body gain
kg	= 0.043 x ME of diet
Target gain	= daily weight gain target

Process steps for calculations

1	Z	= LW÷ SRW
2	NE per kg EBG	= 8.7 + 18.3 ÷ (1+ exp (-6 x(Z-0.4)
3	ME per kg EBG gain	= NE per kg EBG ÷ k_g
4	ME per kg LW gain	= ME per kg EBG ÷ 0.92
5	ME growth	= ME per kg LW x target gain

Equation ME_{growth} ME requirements for the growth		Worked example: heifer
SRW	Standard reference weight (what the heifer will weigh when mature and at BCS 5)	= 600 kg
LW	Current live weight	= 340 kg
Z	= LW÷ SRW	= 340 ÷600 = 0.57
EBG	= Empty body gain	
kg	= 0.043 x ME of diet	= 0.043 x 11 = 0.47
Target gain	= daily weight gain target	0.7 kg per day
ME of diet	Metabolisable energy of diet	11 MJ ME

1. Z = LW÷ SRW
   Z = 340 ÷600 = 0.57

2. NE per kg EBG = 8.7 + 18.3 ÷ (1+ exp(-6 x(Z-0.4)
   NE per kg EBG = 8.7 + 18.3 ÷ (1+ exp(-6 x(0.57-0.4) = 22

3. ME per kg EBG gain = NE per kg EBG ÷ kg
   ME per kg EBG gain = 22 ÷ 0.47 = 46.8

4. ME per kg LW gain = ME per kg EBG ÷ 0.92
   ME per kg LW gain = 46.8 ÷ 0.92 = 50.9

5. ME per day for target gain = ME per kg LW x target gain
   ME per day for target gain = 50.9 x 0.7

Total daily requirement for growth = 36 MJ ME

Process used: calculated energy for maintenance, added nothing for activity and pregnancy, then added energy for growth to get the total

TOTAL DAILY ME REQUIREMENTS FOR THE EXAMPLE HEIFER

$ME_{maintenance\ (including\ E_{graze})}$ = 45 MJ ME

Plus

$ME_{activity}$ = 0 MJ ME

Plus

$ME_{pregnancy}$ = 0 MJ ME

Plus

ME_{growth} = 36 MJ ME

Total = 81 MJ ME per day

This is helpful if you want to build your own spreadsheet or if your heifers are significantly different to the assumptions used in the reference tables.

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FEED CONVERSION EFFICIENCY

Feed conversion efficiency or FCE is most commonly defined as the kilograms of milk or grams of milk solids produced per cow per year divided by the kilograms of feed dry matter offered per cow per year. It is a physical measure of feeding system performance on a dairy farm.

Understanding how efficiently feed is converted into milk is a key question for those seeking to improve productivity and profitability.

There are many factors that can influence the conversion of feed into milk. The interplay of these factors makes making judgements about the efficiency of the system difficult without a systematic means of measurement.

Factors influencing milker feed conversion efficiency	
Cow factors	• FCE is influenced by the physical condition of the cow, how efficiently the digestive system is operating etc. • If the cow is sick or poorly nourished, the overall output of the system will be compromised.
Feed factors	• FCE can be influenced by feed quality and palatability which in turn influence digestibility and levels of wastage. • The level of feeding also impacts FCE due to the 'dilution of maintenance' principle. For example, if the feeding level is very low, a large proportion of feed energy input is utilised for maintenance and not much is left over for production.
Management factors	• FCE can be influenced by farming system and management decisions: the what, when, how to feed. • These decisions will influence many things including the health of the cow, rumen health, the balance of the diet (energy/protein), feed on offer and, level of wastage (intake).

With feed costs such a large proportion of variable and total costs on a dairy farm, it is important to measure the efficiency with which feed is converted into milk.

FCE should always be used in conjunction with other farm physical performance measures and financial performance measures (such as annual milk operating profit and return on assets).

FCE is a ratio, expressed in terms of the amount of milk produced per kilogram of feed given to your herd.

FCE can be measured for the milking herd on an annual basis, seasonally within each year or on a daily basis.

CALCULATING ANNUAL MILKER FCE

$$\text{Annual milker FCE} = \frac{\text{kgs milk produced or grams of milk solids/ cow / year}}{\text{kgs pasture + kgs fodder + kgs grain + kgs other feeds fed / cow / year (DM basis)}}$$

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FCE & NEGATIVE ASSOCIATED EFFECTS

Diets formulated to provide specific levels of ME may fail to do so because the cow may not be able to effectively digest dietary carbohydrates due to negative associated effects.

This issue can be improved through better diet management, with appropriate adjustment of the diet such as:

- increasing the content of physically effective fibre (peNDF)
- replacing large discrete meals of concentrates with partial mixed rations (otherwise referred to as PMR)
- avoiding slug feeding if feeding high amounts of concentrates, in particular at milking times.

The principal objective of these strategies is to limit the depth of the inevitable twice-daily decline in rumen pH, with the associated compromise of the activity of the rumen microbes.

Where pasture feeding is an integral part of a cow's diet, the concept of peNDF becomes a little hazy because a suitable technique is yet to be developed to measure it. A rule of thumb that might be used is to apply acid detergent fibre (ADF) concentration as a surrogate.

Negative associative effects apart, the factor having the largest impact on achieved versus planned production is wastage of feeds. This is particularly important with conserved forage supplements. However, in grazing systems, substitution can also be responsible for a considerable waste of pasture.

Failure to optimise NDF digestion is often the key determinant of achieved production compared with planned production and will inevitably adversely impact on feed conversion efficiency.

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The key to avoiding a decline in rumen pH is regulating the time and rate of the feeding of rapidly fermentable feeds. Cereal grain, lush clover and turnips can contribute to lowering rumen pH.

ESTIMATED ME AND LEVEL OF FEEDING

Most commonly, ME is estimated from digestibility. As it is not feasible to routinely measure the in vivo digestibility of feeds, it is generally estimated using in vitro systems, usually incorporating standard feeds of known in vivo digestibility from mature wether sheep fed at maintenance.

This has important implications when using estimated digestible energy or ME values for pastures and supplements in formulating diets for lactating dairy cows where intakes, and rates of passage through the digestive system, are high relative to those of non-lactating animals fed at maintenance.

The decline in digestibility of energy as feed intake increases should be accounted for when formulating diets, but it is more common for dairy farmers and their advisers to assume that the estimated ME of the diet does not change with the level of intake or when mixed feeds are consumed.

Research at Kyabram measured in vitro and in vivo digestibilities and provides a clear example of what this oversight means when formulating diets or feed budgeting:

- *in vitro* DMD of grass hay was 74% digestible (about 10.5 MJ/kg DM)
- *in vivo* DMD in lactating dairy cows was 64% digestible (about 8.9 MJ/kg DM).

When fresh Persian clover herbage was fed instead, the results were:

- *in vitro* DMD was 82% digestible (ME of 12.0 MJ/kg DM)
- *in vivo* DMD was 75% digestible (ME of 10.7 MJ/kg DM).

The decline in ME due to the level of feeding equated to 4–5% for each unit increase in feeding level above maintenance (i.e. for each one percentage unit increase in intake expressed as a percentage of live weight), which fits in with research done with total mixed rations or complete diets.

The practical implication of this result is that using ME values estimated from in vitro DMD to formulate diets and to do feed budgets without the appropriate adjustments for intake may greatly underestimate the amount of feed that needs to be supplied.

FCE TARGETS FOR DIFFERENT FEEDING SYSTEMS

Five main feeding systems have been described that match approaches to feeding commonly adopted in Australia.

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CLASSIFICATION OF AUSTRALIAN DAIRY SYSTEMS

1. Low bail system: grazed pasture and other forages with less than one tonne grain/concentrate / cow/year fed in the bail during milking.
2. Moderate-high bail system: grazed pasture and other forages with more than one tonne grain/ concentrate /cow/year fed in the bail during milking.
3. Partial mixed ration (PMR) system: pasture grazed for most or all of the year plus partial mixed ration on a feed pad, with or without grain/concentrate feed in the bail.
4. Hybrid system: pasture grazed for less than nine months per year plus partial mixed ration on a feed pad, with or without grain/concentrate feed in the bail.
5. Total mixed ration (TMR) system: zero grazing, cows fed total mixed ration and may be housed.

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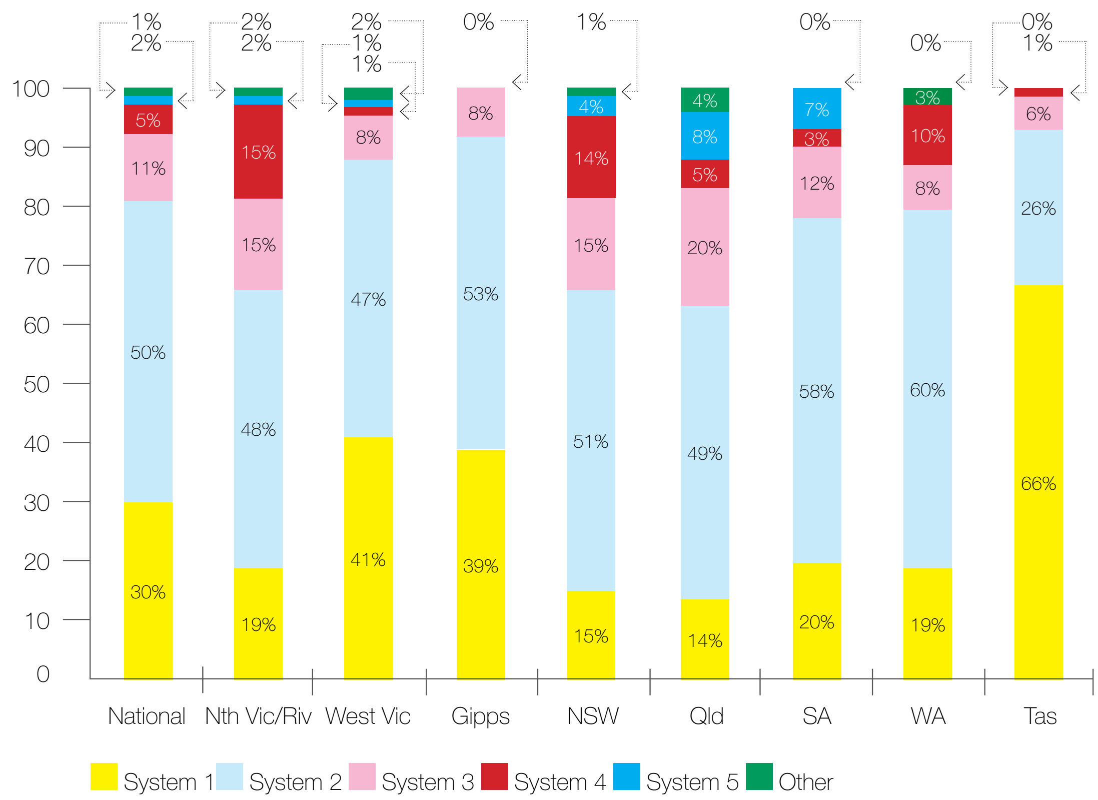
Recent studies in Tasmania (Dairy Australia TasMilk-60 study, 2010) and Queensland (QDAFF FCE survey, 2011–12) have shown that FCE varies widely between commercial dairy farms using the same feeding system.

On many farms FCE is 0.2 or more kg milk / kg feed dry matter below the target for their feeding system. On these farms there is therefore a significant opportunity to improve FCE and reduce feed cost per kg of milk.

A number of things influence a farmer's choice of feeding system including the farm's natural resources, how variable the climate is, the extent to which they prefer to focus on pasture or cows, equity levels, labour constraints and employment, technology and machinery preferences.

Proportion of farmers using the five feeding systems across Australian dairy regions (2010)



Source: Dairy Australia 2010.

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A key difference as farmers move across the spectrum from feeding system 1 to 5 is increasing capital investment in feeding infrastructure and equipment.

Farmers who choose to invest in systems 3, 4 or 5 may do so for many reasons, including a desire to:

- achieve higher cow feed intakes and better control over diets
- utilise cost-effective co-products
- reduce levels of feed wastage
- provide passive or active cooling to cows in hot weather to sustain daily feed intake and milk production
- control wet weather damage to pastures.

TARGETS FOR FCE

Feed conversion efficiency (FCE) targets are recommended for each of the five main feeding systems.

FCE indicates if the overall feeding system is operating efficiently.

FCE targets vary between feeding systems, with more highly controlled feeding systems such as housed total mixed ration systems expected to achieve greater FCE than low-input-pasture-based systems.

If a system is achieving poor FCE compared to the target for that feeding system, a systematic analysis of all aspects of the feeding system needs to be undertaken to determine the likely cause/s and action to improve FCE in future years.

Achievable annual FCE targets for milking cows for the five different feeding systems are expressed in terms of litres of energy-corrected milk (standardized for protein and fat concentrations) or grams of milk solids per kilogram of feed dry matter.

Annual milker feed conversion efficiency targets for the five feeding systems *(including a 60-day dry period)*			
Feeding system		**Litres energy-corrected milk / kg feed DM**	
		Achievable target	Take action if less than
1	Low bail system	1.0	0.9
2	Moderate-high bail system	1.2	1.1
3	Partial mixed ration system	1.3	1.2
4	Hybrid system	1.4	1.3
5	Total mixed ration system	1.6	1.45
Feeding system		**Grams milk solids / kg feed DM**	
		Achievable target	Take action if less than
1	Low bail system	75	68
2	Moderate-high bail system	90	83
3	Partial mixed ration system	100	92
4	Hybrid system	105	98
5	Total mixed ration system	120	109
Source: Dairy Australia 2010.			

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Feed conversion efficiency targets are achievable in well-managed systems, with minimal wastage, good quality feed, minimal feed gaps and good rumen function throughout the year.

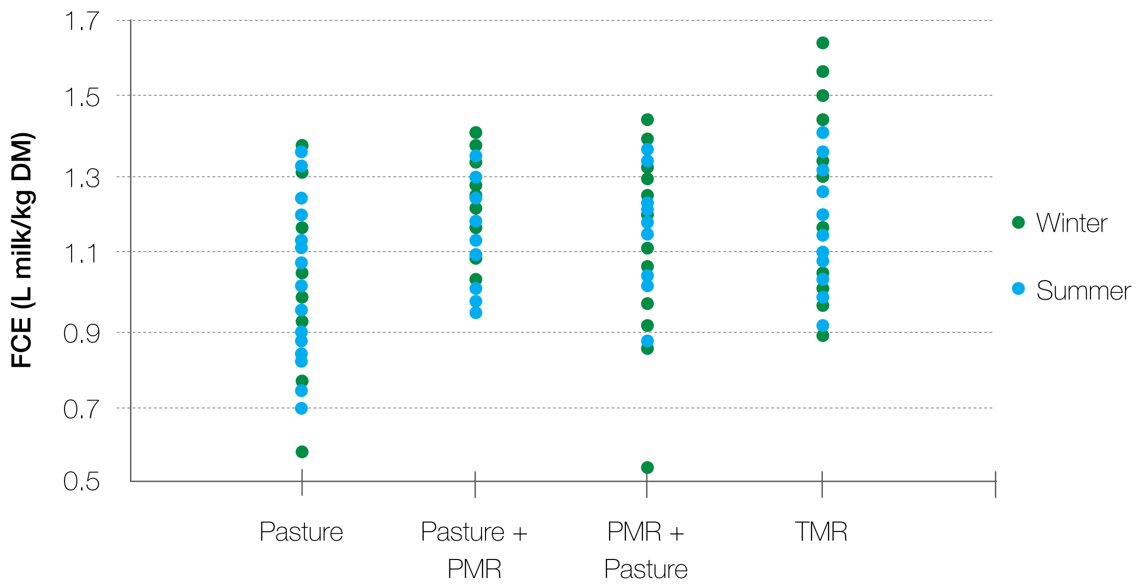
The targets for feed conversion efficiency are lower in feeding systems 1 and 2 than those using systems 3, 4 and 5 for several reasons:

- the amount of pasture a cow is able to eat per day is limited
- daily bouts of pasture and grain consumption (grazing and consumption of grain / concentrates in the bail at milking) cause irregular daily rumen pH patterns and reduced efficiency of fermentation in the rumen
- there may be periods during the year when feed gaps (quantity and quality) exist due to limited pasture and cow nutrient intakes may not be optimised
- feeding out of hay and silage on the ground (rather than on a feed pad) may result in substantial wastage (as high as 30% or more)
- walking and grazing activity consumes energy.

Given the higher capital and operating costs associated with systems 3, 4 and 5, higher feed conversion efficiencies need to be achieved than for systems 1 and 2 to be profitable.

Higher feed conversion efficiencies are possible using feeding systems 3, 4 and 5 because they enable higher daily feed intakes to be achieved, provide greater control over feed quality and feed wastage, and allow a more stable and efficient rumen to be maintained.

Qld feed conversion efficiency survey



Source: David Barber, QDAFF 2013.

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Fulkerson et al. (2005) undertook a study to determine the effects of accurately allocating pasture on a daily basis to cows grazing either ryegrass or kikuyu pasture, and supplemented with concentrates and hay.

The study found that the benefit of consistently allocating pasture translated to about a 10% improvement in milk production in comparison to the typical under- and over-feeding of pasture that occurs between days on dairy farms.

See: Fulkerson WJ, McKean K, Namdra KS, Barchia IM (2005) Benefits of accurately allocating feed on a daily basis to dairy cows grazing pasture. *Australian Journal of Experimental Agriculture* **45**, 331–336.

SIX STRATEGIES FOR IMPROVING FCE

There are six key strategies that will optimise FCE and these are applicable across all five feeding systems.

1. Optimise total daily feed intake
   Most of the improvements in FCE that can be achieved on farms will be associated with increased feed intake. Increasing feed intake leads to a greater proportion of ME being used to produce milk and a smaller proportion being used for maintenance. For example, a cow fed to produce 10,000 litres / year uses two-thirds of its feed to produce milk compared with only half in a cow fed to produce 5,000 litres / year.

2. Maintain high feed quality
   Cows are more efficient when fed a high-quality diet.

3. Maintain good rumen function
   A healthy rumen digests feed efficiently. Any upset in rumen conditions negatively impacts digestion and extraction of nutrients from feed.

4. Minimise feed gaps
   Maintain consistent feed intakes day-to-day and week-to-week, to minimise 'hollows and humps' in production.

5. Minimise feed wastage
   Any feed wasted immediately impacts FCE.

6. Minimise energy losses
   Excessive energy losses due to walking, grazing, heat and cold stress will reduce FCE.

Even though farmers will say they allocate the same amount of pasture every day, on-farm monitoring has clearly demonstrated that this does not happen. The implications include:

- underallocation of pasture results in compromised pasture regrowth
- overfeeding (of supplements or pasture) results in wasted pasture that may never be eaten.

Practice in allocation makes improvement possible.

ESTIMATING FEED CONVERSION EFFICIENCY

The pasture consumption and feed conversion efficiency calculator developed by DELWP provides the dairy industry with a robust, scientifically sound method for calculating annual pasture removal and FCE. Search Agriculture Victoria Pasture consumption calculator.

ADVISER ALERT

In Australia, milker FCE is normally measured on an annual basis.

It is possible to measure feed conversion efficiency on a daily basis, however expectations vary dependant on the stage of lactation due to tissue mobilisation and deposition.

Beever and Doyle (2007) showed that, in the first eight weeks of lactation, measured FCE declined from 2.2 to 1.5 kg of energy corrected milk/kg DM consumed. When this was corrected for tissue mobilisation, the range narrowed to 1.6 to 1.4 kg energy corrected milk/kg DM consumed.

Conversely, FCE in late lactation can be around 1.0–1.2 kg of energy corrected milk/kg DM consumed, but when tissue deposition is accounted for the FCE values increase.

Thus, the effects of tissue mobilisation and deposition on estimates of FCE indicate that it is necessary to interpret estimates made at different stages of lactation.

The effects must be considered in the light of known principles of energy metabolism and estimates of any changes in body condition score.

A herd's monthly FCE must be interpreted based on the calving system being used. The FCE of a year-round herd will be relatively steady from month to month, as individual cows will be at many different stages of lactation. In contrast, the monthly FCE of a seasonal calving herd will follow a distinct pattern, as most cows are in the same stage of lactation.

PARTIAL MIXED RATIONS IN VICTORIAN CONTEXT

The use of partial mixed rations (PMR) in Victorian pasture-based dairy systems is a relatively new concept and the research behind it is currently in progress at Ellinbank.

Being a compromise between pasture/bail-fed concentrates and total mixed rations, PMR is a diet where a mixed ration forms part of the diet in conjunction with grazed feed.

If milk can be economically produced from a PMR, it could be used on a daily basis in association with pasture when the pasture is in short supply or when grazing is limited by wet conditions as a pasture management tool.

Theoretically, a PMR should provide many of the nutritional benefits of a total mixed ration without the full capital expense required of a total mixed ration (TMR) system.

A well-designed PRM system should enable increased intake and milk production. It should also increase feed conversion efficiency compared to feeding concentrates in the bail and fodder in the paddock.

The Flexible Feeding Systems research at Ellinbank suggests that milk production advantages from a PMR occur when a PMR is feed at greater than 10 kg dry matter per cow per day: feeding 5 kg is not worth it.

These strategies for improving feed conversion efficiency in each of the five main feeding systems were developed by Little S, Lean I, Wales W, King R and Doyle P (Dairy Australia Grains2Milk fact sheet, 2010).

STRATEGIES FOR IMPROVING FCE

1. Improving FCE – low bail system

Pasture + other forages + low grain / concentrate feeding in bail

- Select suitable pasture species/cultivars and grow pasture to farm's potential (as dependent on climate, soil fertility, water, nitrogen etc.).
- Use appropriate stocking rate to manage pastures effectively.
- Optimise pasture intakes (high pasture allowances, high digestibility for as much of the year as possible).
- Use grain and other supplements to alleviate seasonal feed gaps and extend lactations.
- Provide adequate effective fibre in the diet at all times to promote chewing and saliva production.
- Minimise energy losses such as from excessive walking and excessive body condition changes during year.
- Manage heat stress effectively in hot weather to minimise the decrease in daily feed intake and increase in energy required for maintenance.

Feeding system	**Grams milk solids per kg feed DM**	
1. Low bail system	Achievable target	Take action if less than
Pasture + forages + low grain/concentrate in bail	75	68
Feeding system	**Kg energy-corrected milk per kg feed DM**	
1. Low bail system	Achievable target	Take action if less than
Pasture + forages + low grain/concentrate in bail	1.0	0.9

2. Improving FCE – moderate-high bail system

Pasture + other forages + mod.-high grain / concentrate feeding in bail

As per system 1 PLUS:

- Greater focus on adequate effective fibre in the diet to promote chewing and saliva production.
- Gradual changes to grain feeding rates (an individual cow ID feeding system in the dairy assists with this).
- Use rumen modifiers, buffers, neutralising agents, probiotics.
- Transition feeding program before calving.
- Protein and mineral supplements.
- Minimise feed wastage (especially fodder) + / - consider.
- Use slower-fermenting grains such as corn with wheat / barley.
- Three times a day milking (especially if using high grain feeding rates).

Feeding system	**Grams milk solids per kg feed DM**	
2. Moderate-high bail system	Achievable target	Take action if less than
Pasture + forages + moderate-high grain/concentrate in bail	90	83
Feeding system	**Kg energy-corrected milk per kg feed DM**	
2. Moderate-high bail system	Achievable target	Take action if less than
Pasture + forages + moderate-high grain/concentrate in bail	1.2	1.1

3. Improving FCE – partial mixed ration system

Pasture + PMR +/- grain / concentrate feeding in bail

As per system 2 PLUS:

- Greater focus on:
  - quality of fodder, grain and other supplements (used in PMR)
  - formulation of a nutritionally balanced diet (pasture plus PMR).
- Correct additions and processing of feed ingredients in mixer wagon.
- Incorporate most of grain in PMR rather than feed in the bail.
- Sequence PMR feeds carefully each day (1X or 2X) with grazing and bail feeding to optimise intakes and maintain rumen as stable as possible.
- Manage feed-pad well:
  - adequate feed space and access to drinking water
  - fresh, highly palatable feed at all times
  - feed sorting and wastage minimised.

Feeding system	**Grams milk solids per kg feed DM**	
3. Partial mixed ration system	Achievable target	Take action if less than
Pasture + PMR +/- grain/concentrate in bail	100	92
Feeding system	**Kg energy-corrected milk per kg feed DM**	
3. Partial mixed ration system	Achievable target	Take action if less than
Pasture + PMR +/- grain/concentrate in bail	1.3	1.2

4. Improving FCE – hybrid system

Hybrid system (grazed pasture for < 9 months per year + PMR on feed pad +/- grain / concentrate in bail)

As per systems 2 / 3 & 5 PLUS:

- correct timing and a smooth, gradual transition:
- from pasture plus supplements to full TMR in late spring
- from TMR back to pasture plus supplements in autumn.

Feeding system	Grams milk solids per kg feed DM	
4. Hybrid system	Achievable target	Take action if less than
Pasture grazed for less than nine months per year + PMR +/- grain/concentrate in bail	105	98
Feeding system	**Kg energy-corrected milk per kg feed DM**	
4. Hybrid system	Achievable target	Take action if less than
Pasture grazed for less than nine months per year + PMR +/- grain/concentrate in bail	1.4	1.3

5. Improving FCE – total mixed ration system

TMR system (zero grazing, cows housed and fed TMR)

As per system 3 PLUS:

- Greater attention to:
  - diet formulation, with more focus on amino acids and minerals, and possible use of fat supplements
  - keeping feed as fresh as possible (1 versus 2 mixes per day).
- Push feed up to cows several times per day.
- Other strategies to promote high daily feed intakes and minimise feed wastage.

Feeding system	**Grams milk solids per kg feed DM**	
5. Total mixed ration system	Achievable target	Take action if less than
Zero grazing, cows housed and feed TMR	120	109
Feeding system	**Kg energy-corrected milk per kg feed DM**	
5. Total mixed ration system	Achievable target	Take action if less than
Zero grazing, cows housed and feed TMR	1.6	1.45

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Search for *Dairy Australia Website Nutrition Management* for further information on:

- Pastures, forages and crops
- Supplementary feeds
- Feeding systems
- Nutrition management.

You can also access free on-line tools, including:

- Pasture Consumption and FCE Calculator
- Feed Report tool.

REFERENCES & FURTHER READING

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Search for *Dairy Australia Fact Sheet: Feed conversion efficiency* A key measure of feeding system performance.

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FEED BUDGETING

Feed costs comprise around 40–65% of total costs in an Australian dairy farming operation, more in dry conditions.

The mean wastage of hay recorded in the scientific literature is 17% of the DM offered but the range is from 4–77%.

The main factors affecting the degree of wastage are:

- storage method
- packaging method
- feeding out method
- amount of fodder on offer and its palatability/quality
- exposure to wet weather.

Limiting cattle trampling of fodder is one of the best ways to reduce feed-out losses. Closely matching feed supplied to animal requirements will reduce feed-out losses too.

Feed budgeting estimates the amount of feed that needs to be provided in the future.

If a diet is formulated incorrectly today, it can be adjusted tomorrow.

If the amount of feed budgeted for in six months time is underestimated, the ramifications can go way beyond targeted production levels.

Feed budgeting incorporates a similar process to that used for diet formulation in that requirements and supply need to be considered and equated with the prospective costs of feeds.

Ideally, feed budgeting takes into account wastage and associative effects (including the reduction of ME due to level of feeding) as well as incorporating the costs of prospective feeds.

ADVISER ALERT

Feed budgeting traps

Avoid the following traps to create a good feed budget.

- Make sure that the stock count is accurate.
- Check that your ME requirements are realistic.
- Make sure you account for feed wastage.
- It is important to check feed on hand to make these estimates as good as they can be: you think there are 200 bales of silage but on counting them find 150.
- Don't forget to include all classes of stock: milkers, dry cows, yearlings and calves.
- Make sure you use ME, not kgs DM.

FEED BUDGETING IN THREE STEPS

Step 1: Calculate monthly feed demand

a. Count how many milkers, dry cows, yearlings and calves there are to feed and milk production and growth targets.

b. Calculate the daily metabolisable energy (ME) requirements of each class of stock.

c. Calculate tonnes of dry matter (DM) required for all stock each month, based on the animals' daily ME requirements and stock numbers.

Step 2: Calculate total feed deficit for each month

a. Calculate tonnes of home-grown DM available each month (pasture, other standing crops, silage and hay on hand).

b. Subtract tonnes of home-grown DM from tonnes of DM required for all stock each month.

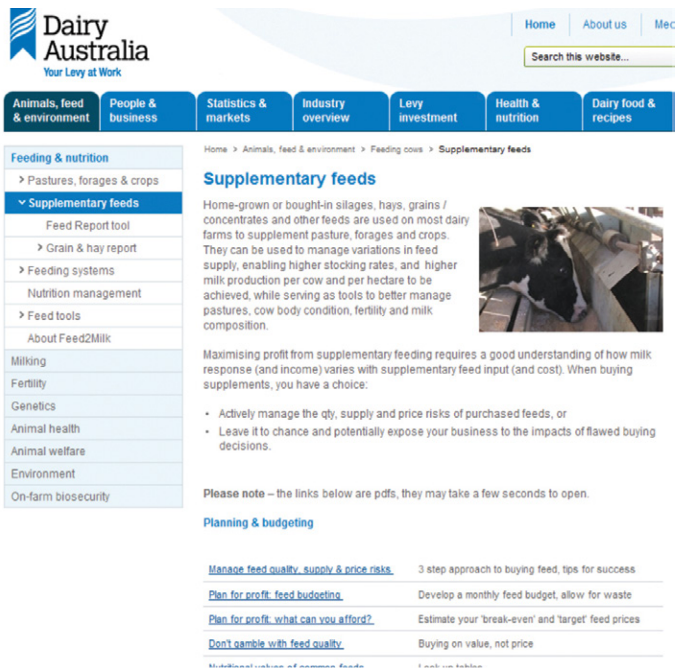
Step 3: Calculate quantities of each bought-in feed you require each month

a. Describe what feeds you intend to buy to fill the feed deficit for each month.

b. Formulate diets for each class of stock: milkers, dry cows, yearlings and calves.

c. Using these diets and the stock numbers from step 1, calculate the total tonnes of each feed that need to be bought each month.

For more information on calculating each step of the feed budget, see Dairy Australia Website: Supplementary feeds.



Dairy Australia
Your Levy at Work

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Feeding & nutrition
- Pastures, forages & crops
- Supplementary feeds
  - Feed Report tool
  - Grain & hay report
- Feeding systems
- Nutrition management
- Feed tools
- About Feed2Milk

Milking
Fertility
Genetics
Animal health
Animal welfare
Environment
On-farm biosecurity

Home > Animals, feed & environment > Feeding cows > Supplementary feeds

Supplementary feeds

Home-grown or bought-in silages, hays, grains / concentrates and other feeds are used on most dairy farms to supplement pasture, forages and crops. They can be used to manage variations in feed supply, enabling higher stocking rates, and higher milk production per cow and per hectare to be achieved, while serving as tools to better manage pastures, cow body condition, fertility and milk composition.

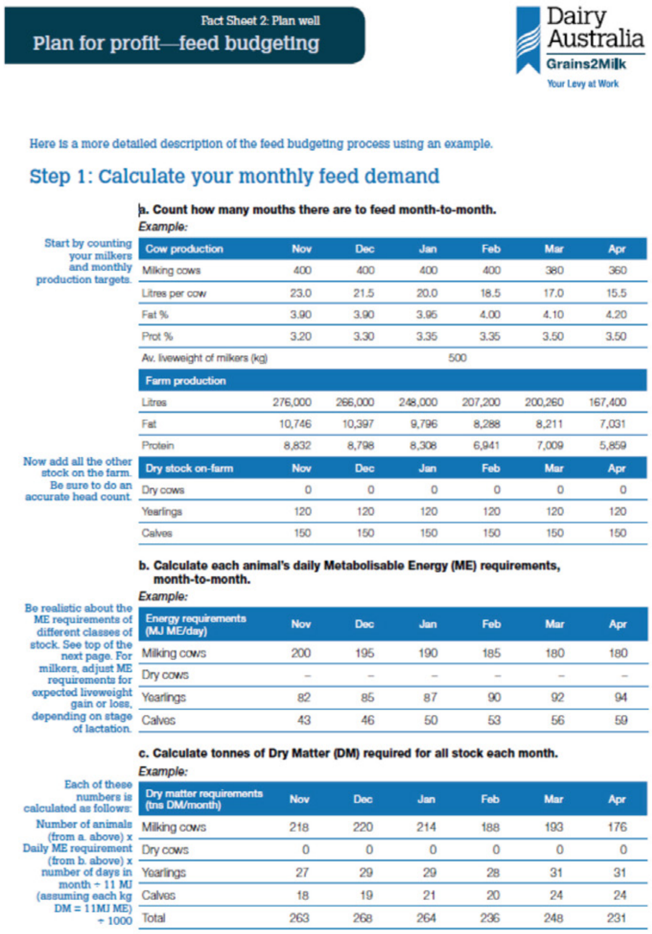
Maximising profit from supplementary feeding requires a good understanding of how milk response (and income) varies with supplementary feed input (and cost). When buying supplements, you have a choice:

- Actively manage the qty, supply and price risks of purchased feeds, or
- Leave it to chance and potentially expose your business to the impacts of flawed buying decisions.

Please note – the links below are pdfs, they may take a few seconds to open.

Planning & budgeting

Manage feed quality, supply & price risks	3 step approach to buying feed, tips for success
Plan for profit: feed budgeting	Develop a monthly feed budget, allow for waste
Plan for profit: what can you afford?	Estimate your 'break-even' and 'target' feed prices
Don't gamble with feed quality	Buying on value, not price



Fact Sheet 2: Plan well

Plan for profit—feed budgeting

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Here is a more detailed description of the feed budgeting process using an example.

Step 1: Calculate your monthly feed demand

a. Count how many mouths there are to feed month-to-month.

Example:

Start by counting your milkers and monthly production targets.

Cow production	Nov	Dec	Jan	Feb	Mar	Apr
Milking cows	400	400	400	400	380	360
Litres per cow	23.0	21.5	20.0	18.5	17.0	15.5
Fat %	3.90	3.90	3.95	4.00	4.10	4.20
Prot %	3.20	3.30	3.35	3.35	3.50	3.50
Av. liveweight of milkers (kg)			500			
Farm production						
Litres	276,000	266,000	248,000	207,200	200,260	167,400
Fat	10,746	10,397	9,796	8,288	8,211	7,031
Protein	8,832	8,798	8,308	6,941	7,009	5,859

Now add all the other stock on the farm. Be sure to do an accurate head count.

Dry stock on-farm	Nov	Dec	Jan	Feb	Mar	Apr
Dry cows	0	0	0	0	0	0
Yearlings	120	120	120	120	120	120
Calves	150	150	150	150	150	150

b. Calculate each animal's daily Metabolisable Energy (ME) requirements, month-to-month.

Example:

Be realistic about the ME requirements of different classes of stock. See top of the next page. For milkers, adjust ME requirements for expected liveweight gain or loss, depending on stage of lactation.

Energy requirements (MJ ME/day)	Nov	Dec	Jan	Feb	Mar	Apr
Milking cows	200	195	190	185	180	180
Dry cows	–	–	–	–	–	–
Yearlings	82	85	87	90	92	94
Calves	43	46	50	53	56	59

c. Calculate tonnes of Dry Matter (DM) required for all stock each month.

Example:

Each of these numbers is calculated as follows: Number of animals (from a. above) x Daily ME requirement (from b. above) x number of days in month ÷ 11 MJ (assuming each kg DM = 11MJ ME) ÷ 1000

Dry matter requirements (tns DM/month)	Nov	Dec	Jan	Feb	Mar	Apr
Milking cows	218	220	214	188	193	176
Dry cows	0	0	0	0	0	0
Yearlings	27	29	29	28	31	31
Calves	18	19	21	20	24	24
Total	263	268	264	236	248	231

KEY RESOURCE

Search for *Feedout checkout: a decision support tool* for a decision support tool designed to assist dairy farmers analyse whether the benefits from reducing wastage are enough to justify the capital expenditure on a feed pad and machinery.

FEED WASTAGE

To maintain profitability, it is imperative that all feeds are used as efficiently as possible, both within the animal and in the feeding system.

Wastage of feed cannot be totally prevented but the aim should be to minimise it.

Feeding grain in the dairy at milking times or total mixed rations on concrete feeding strips under cover minimises wastage, potentially to less than 5%.

Losses of dry matter and nutritive value of hay and silage can occur at the harvesting, storage and feeding-out stages.

Harvesting and conservation losses will have already occurred when farmers are estimating the amount of hay or silage needed for their animals.

If not considered, the extent of losses at feed-out can potentially result in animals being grossly underfed and/or expose animals to acidosis.

Wastage adversely impacts feeding costs.

Providing amounts that are eaten in a couple of hours limits waste.

Using intact bales with no feeder potentially results in the greatest amount of wastage. Rolling bales out on the ground is only marginally better.

Feeders reduce wastage, particularly if they are under cover, but their effectiveness varies.

Low-quality, unpalatable fodder results in animals rejecting much of that on offer.

Livestock foul, trample and use conserved fodder for bedding when it is fed without restriction.

Conserved fodder production/purchase costs remain the same whether the food ends up inside an animal or not.

Farmers and their advisors generally budget the cost of feed on an as-bought basis rather than allowing for any wastage during feed-out.

If wastage is 40% rather than 5%, this difference can change a 3 t/animal feed inventory to 4 t/animal.

For fodder costing 15 cents/kg to purchase, this level of wastage would be responsible for increasing the cost of feeding each animal by $150.

The costs and savings of reducing wastage need to be weighed up in each situation.

Greater spending on capital items will generally be associated with reductions in wastage.

Large bale systems were designed to minimise labour, not waste, while feeding hay each day minimises waste but increases labour costs.

In 2009, Dairy Australia's Grains2Milk program commissioned SBS*cibus* to conduct a study of feed wastage rates on 50 commercial dairy farms across Australia which use a range of different feed-out methods.

Key findings from the study were as follows.

There is substantial variation in the amount of feed refusal and wastage between and within feed-out methods on Australian dairy farms.

Feed wastage was significantly greater with feed-out methods 1 and 2 (the feed-out methods with less structure and investment) than with other feed-out methods.

Within all feed-out systems, some farmers achieved very low wastage. These variations may reflect variations in farm management within a particular system (for example, feed-out procedure, feed bunk management, forage quality and operator skill).

The following table summarises the feed refusal and wastage rates (median % dry matter, with range in brackets) measured on 50 commercial dairy farms across Australia which use a range of different feed-out methods.

!

KEY RESOURCE

For a full summary of the key findings from this study, guidelines for measuring feed wastage on farms and a four page feed wastage fact sheet, search for *Dairy Australia Feed wastage study.*

Feed refusal and feed wastage rates for 6 common feed–out methods used on Australian dairy farms

Feed–out method	% DM refusal (range)	% DM wastage (range)	Total % estimated feed wastage (range)
1 Temporary, relocatable – bare area & ring feeder	5% (0–14%)	13% (2–28%)	18% (4–36%)
2 Feed allocated on pastures in the paddock	4% (0–9%)	6% (0–15%)	9% (1–23%)
3 Semi–permanent feed–out area – compacted surface and low-cost troughing	2 (0–6%)	4% (0–16%)	6% (0–17%)
4 Permanent, basic but functional feed–out facility – purpose-built with compacted surface and concrete troughing	3% (0–7%)	2% (1–5%)	2% (1–5%)
5 Permanent, minimal waste, maximum control – purpose-built feed-out facility, cement surface and one or more feed alleys	6% (0–22%)	2% (0–6%)	2% (0–6%)
6 Grain feeding in the dairy (rotary and herringbone)	7% (0–39%)	1% (0–1%)	1% (0–1%)

Source: Summary report Feed wastage study (2009). Dairy Australia.

Notes on the feed wastage study

- The assessment of feed wastage was conducted under dry conditions and may not reflect the full range of wastage that might occur under wet conditions.
- The amount of uneaten / leftover feed was classified as 'refusal' and 'wastage'.
- Refusal is the amount of feed that remains in the feed troughs, on pasture and on bare ground, and does not get consumed by cows after a certain period of time following the feed-out. With feed-out methods 1, 2 and 3 the refusal is wasted but with feed-out methods 4 and 5 it can be collected and fed to other cattle.
- Wastage is the amount of feeds that are contaminated with urine or faeces and soil or spread out around the feed-out area and will not be eaten by cows at a later stage.

EXAMPLES OF FEED-OUT METHODS AND WASTAGE

Feed-out method 1

High amount of feed wastage (27%)

Source: search for *Dairy Australia: Feed - don't waste it*

Feed-out method 2

Cereal hay fed on pasture: minor feed refusal and wastage (4.4%)

Source: search for *Dairy Australia Feed - don't waste it.*

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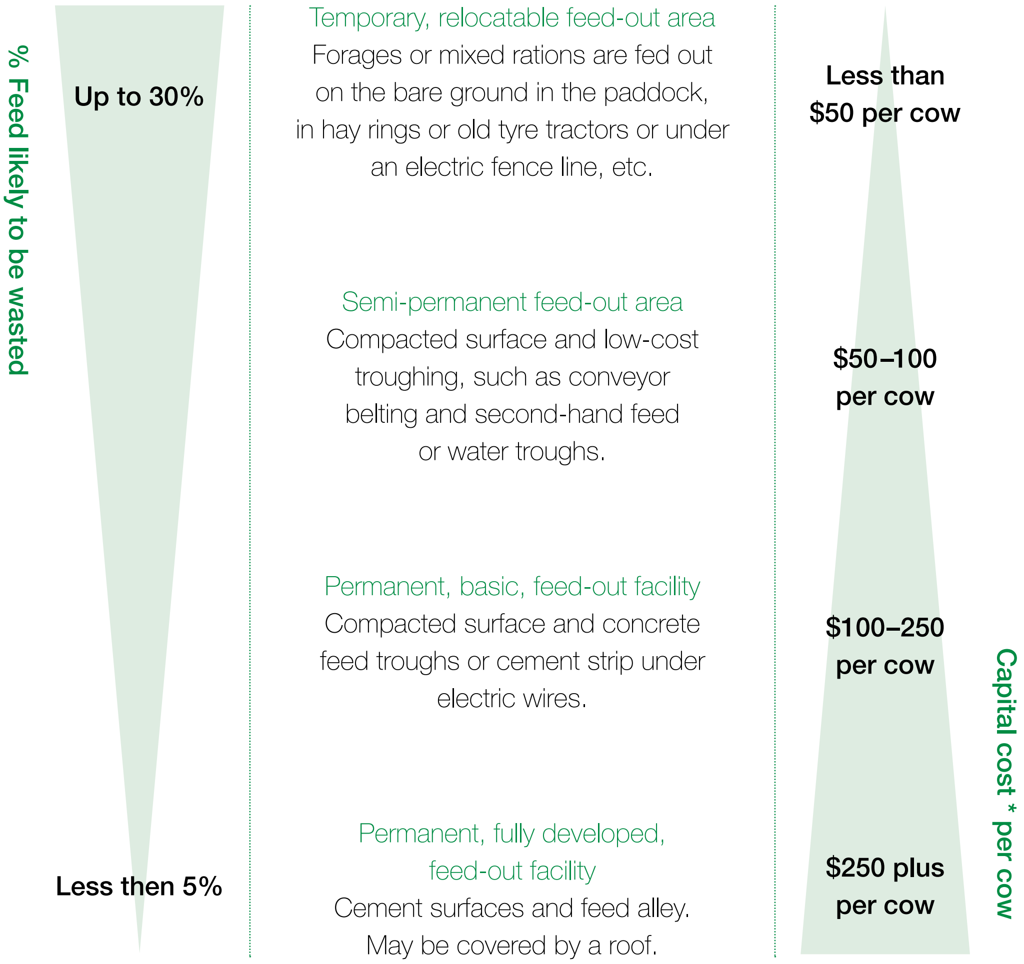
Feed wastage rates vary between different feed-out methods. Low capital cost methods usually waste much more feed than high capital cost methods and visa versa.



* The cost per cow is an example for the feed-out area only. It does not include associated equipment (carts, wagons and tractors) as these may already exist or may be borrowed, leased or purchased, depending on individual circumstances.

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ADVISER ALERT

250 cows, feeding one tonne of bought-in hay per cow per year plus grazed pasture and concentrates in the bail: if hay wastage could be reduced by 10% this would be worth about $5,000 per year (250 X 0.1tn / cow / year at $200/tonne dry matter).

CALCULATING PAYBACK PERIODS

Payback periods on investments for higher capital feed-out facilities are often relatively short, particularly with realistic estimations of the value of feed being wasted in the current system.

Payback calculation example

Cost: $45,000 ($150 per cow)
Basic permanent feed-out facility, purpose-built concrete troughing for 300 cow herd.

Current feed: 10 kg DM PMR per cow per day at $300 per tonne DM in the paddock.

Estimated wastage reduction: ~ 10%
From about 18% to 8%

Saving: 1 kg DM saving per cow per day
A saving of $90 per day or $2,700 per month.

Payback period: $45,000 ÷ $2,700 = 17 months.

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COW NUTRITION AND FERTILITY

Numerous studies have investigated effects of milk production, body condition score and live weight on fertility, but results have varied widely. To date, the influence of nutrition on fertility has not been fully clarified; nevertheless, some effects are clear.

NEGATIVE ENERGY BALANCE

Most dairy cows pass through a period of negative energy balance in early lactation. During this period cows lose weight until their feed intake increases to the point where their dietary energy supply meets their energy demand for milk production.

The modern dairy cow usually conceives at peak lactation, the period of greatest energy stress. Negative energy balance in early lactation is usually the main cause of poor conception rates in dairy cows. The magnitude and/or duration of negative energy balance in early lactation are both important.

During the first three weeks of lactation, negative energy balance delays early ovulation and post-calving recovery of ovulation.

High-yielding cows in prolonged negative energy balance have greater delays.

Negative energy balance may detrimentally impact the oocyte (egg prior fertilisation) that is released after ovulation. It may also effect embryo quality.

First ovulation is delayed because negative energy balance inhibits lutenising hormone pulse frequency and also results in low levels of blood glucose, insulin and insulin-like growth factor-I (IGF-I).

Negative energy balance may also exert other carryover effects on uterine conditions resulting in reduced conception rate to insemination.

!

NEGATIVE ENERGY BALANCE

'Negative energy balance, as indicated by a marked loss in body condition in early lactation when the energy requirements of milk production and maintenance exceed dietary energy intake, is also strongly correlated with poor reproductive performance'. (Auldist 2013).

Butler, WR. (2013) Metabolic and reproductive interactions in dry and transition dairy cows. InCalf Reproduction Symposium, Dairy Australia.

If energy intake is insufficient to meet the demands of milk secretion, as it usually is in early lactation, body reserves are mobilised.

Feeding starch-based concentrates in early lactation (and possibly a rumen-protected fat supplement) may provide some benefit but body condition at calving is the most important variable involved.

For high-yielding dairy cows, achieving high DM intake early post-calving is crucial for resumption of ovulation and development of a corpus luteum of normal size. It is also important for progesterone production required for high fertility.

NEGATIVE ENERGY BALANCE

Bring the cow back to positive energy balance sooner with an energy-dense and optimum protein diet.

A minimal delay to first ovulation following calving allows time for completion of multiple ovarian cycles prior to insemination which, in turn, improves conception rate.

When cows are well-fed, they still experience some degree of negative energy balance. Underfeeding, whether due to management or disease/injury, exacerbates the depth of the negative energy balance.

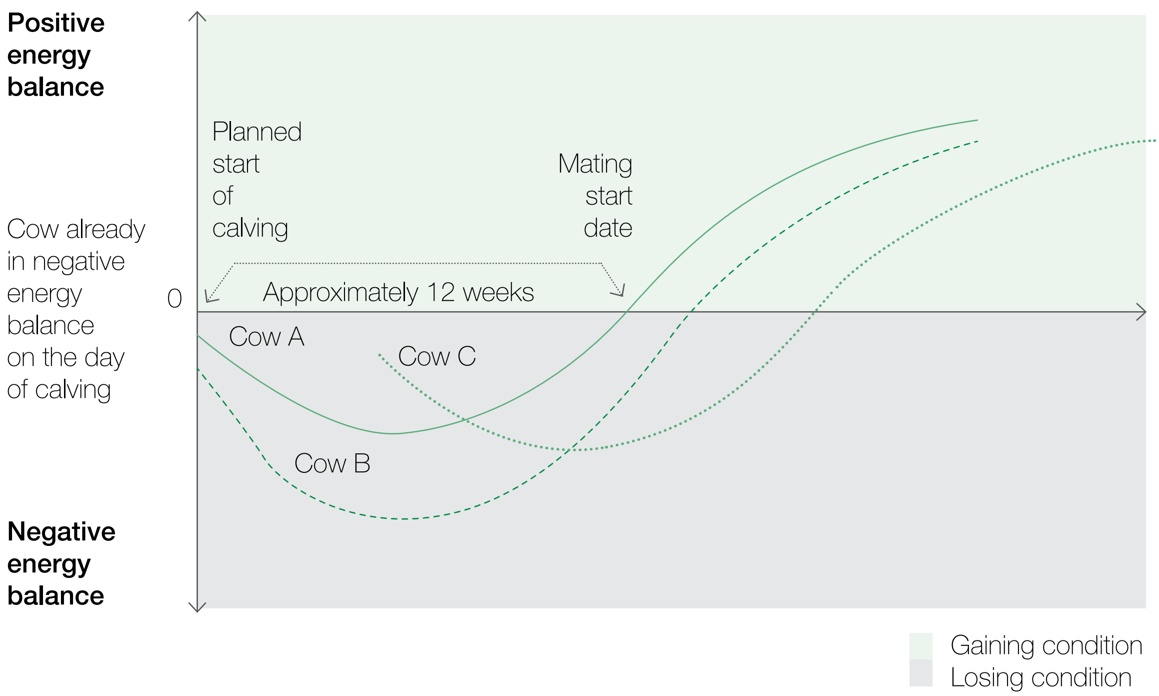
Energy balance of cows in seasonal / split calving systems

Compare the following three cows in one calving group.

Cow A is the ideal cow. She calves early in the calving period in moderate body condition (not too fat or thin for her genetics). Having had a good transition from pregnancy to lactation her post-calving feed intake is reduced but not excessively. She achieves positive energy balance by mating start date so is likely to be highly fertile and get pregnant soon after mating start date.

Cow B also calves early in the calving period, but in very high body condition (well above her genetic BCS target at 10–12 weeks lactation). Her post-calving feed intake is severely reduced, so she drops into much deeper negative energy balance and takes longer than cow A to achieve positive energy balance. She is likely to get pregnant later in the mating period than cow A.

Cow C is very similar to cow A, calving in moderate body condition and having had a good transition from pregnancy to lactation. She follows the same energy balance pattern as cow A but several weeks later as she calved later in the calving period. At mating start date she is at her negative energy balance nadir and unlikely to get pregnant until several weeks later in the mating period.



Negative energy balance is the most likely non-management factor to influence reproductive performance.

Multiple regression models consistently report that body condition change between calving and low point (nadir) is negatively associated with:

- days to resumption of normal oestrus cycling activity
- first service conception rate
- in-calf rates.

The InCalf research study (1996–1999) found that a reduction in average herd BCS change in early lactation from between 0.75 to 1.0 of a score (on 1 to 8 scale) to one between 0.45 to 0.6 is likely to have the following beneficial effects:

- 3% higher 6-week/100-day in-calf rate
- 2% lower not-in-calf rate.

The primary means of controlling the drop in body condition score and amount of body condition loss after calving is through managing calving body condition score.

Severe negative energy balance delays resumption of normal oestrous cycling in high-yielding cows. A major limiting factor is glucose supply.

Maximising the production of glucose precursors (the production of propionate and glucogenic amino acids) is essential.

A propionate diet (i.e. increasing concentrates in early lactation) raises insulin concentrations and reduces the interval from calving to first ovulation.

The inclusion of slowly degraded concentrates provides glucose from the small intestine while limiting the potential for ruminal disturbances. However, the main effect of such a diet seems to be to allow cows to move more quickly towards positive energy after the negative energy balance low point.

For further information see Ch 7.

ADVISER ALERT: RANKING COWS ACCORDING TO PLASMA CONCENTRATIONS OF INSULIN-LIKE GROWTH FACTOR 1

Plasma concentrations of insulin-like growth factor 1 (IGF-1) provide an opportunity for farmers to identify cows that might have some difficulty getting pregnant.

Local research has found that the ranking of plasma concentrations of insulin-like growth factor 1 of cows within a herd remains consistent no matter when it is measured.

Plasma insulin-like growth factor 1 concentrations are positively related to energy intake and therefore milk yield.

Low concentrations is associated with an extended post-calving interval to first ovulation.

In cows where the first post-calving dominant follicle ovulated, concentrations of insulin-like growth factor 1 were 40–50% higher in the first two weeks after calving than in cows where the first dominant follicle failed to ovulate.

This provides a practical means by which farmers could identify those cows that will be most difficult to get back in calf, thereby providing the opportunity to take some sort of remedial action if considered appropriate.

ADVISER ALERT: PROTEIN-TO-FAT RATIOS

Another indicator of reproductive efficiency is protein-to-fat ratios in a herd. Higher protein-to-fat ratios at the start of breeding are associated with an increased likelihood of submission for breeding in the first 21 days of the breeding season.

The positive association between milk protein concentration and in-calf rates was identified in the InCalf research study (1996–1999). It was also found in the InCalf Fertility Data project (2011).

Fulkerson et al. (2001) found that cows with the lowest milk protein content (2.89%) suffered the most severe and prolonged negative energy balance compared with cows with a milk protein content of 3.10%.

As a generalisation, milk protein concentrations are gross indicators of energy intake. Thus, as with testing blood for insulin-like growth factor 1, herd testing can also give an indication of those cows most likely to suffer from reproductive failure.

HIGH DIETARY PROTEIN & FERTILITY

At certain times of the year, the protein content of pasture exceeds the cows' requirements. This excess is exacerbated by the tendency of cows to select a diet even higher in protein than the average of the pasture sward.

Depending on the balance of protein fractions present in the feed and the availability of fermentable carbohydrates, high dietary protein can result in elevated blood concentrations of ammonia, urea or both.

Much of the crude protein in the diet is hydrolysed in the rumen to ammonia, which is used by rumen microbes for microbial protein synthesis.

Excess ammonia, which is toxic, is transported to the liver where it is metabolised to urea or used in the synthesis of amino acids.

Urea is a relatively small molecule and moves freely through cell membrane. It moves from the blood into other areas of the body (like the reproductive tract).

Protein intake may also affect reproduction via direct effects on the uterine environment where toxic by-products of nitrogen metabolism (including ammonium ions from the rumen) may impair sperm, ova or early embryo survival. Such effects may be mediated via changes in uterine pH.

The associated high blood urea concentrations, coupled with suboptimal early luteal progesterone concentrations, have been found to have a detrimental effect on embryo survival.

In summary, there are several possible modes of action of excess protein intake on reproductive performance:

- excess dietary protein may reduce uterine pH making it antagonistic to survival of sperm and embryos
- the effects may be at the level of the oocyte in the follicle and not in the uterus
- high-protein diets may be associated with lower plasma progesterone.

STRATEGIES TO REDUCE EXCESS DIETARY PROTEIN

If excess dietary protein is impacting on reproductive performance, one practical way to counter it is to supplement the diet with an energy supplement in the form of a readily fermentable carbohydrate source.

An alternative strategy is to limit the amount of rumen degradable protein by including a bypass protein. However, while the latter strategy should result in lower concentrations of ammonia in the rumen, there is potential for bypass protein to increase milk yield. This may push a cow into even greater negative energy balance which in turn has a major negative influence on reproductive performance.

The cost of detoxifying excess ammonia to urea may accentuate an already large negative energy balance.

Excess rumen ammonia may be due to high rumen degradable protein or a relative deficiency of dietary energy in the rumen.

High bypass protein may encourage a cow to produce more milk, again accentuating her negative energy balance.

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A NEW ZEALAND STUDY SUGGESTS THAT THE EFFECTS OF HIGH-PROTEIN PASTURE DIETS ARE LESS SERIOUS THAN THOSE REPORTED FROM THE NORTHERN HEMISPHERE

Milk urea measurements, which are often used to identify rumen ammonia issues, are considerably higher in Australia / New Zealand than those recorded in the milk from cows fed typical feed-lot diets.

While this leads Northern Hemisphere nutritionists to suggest that our cows are likely to have major issues, reproductive performance in Australia / New Zealand is better than that typically found in the US / Canada.

This may have come about because Australasian cows have adapted to pasture-based diets over the years. However, the recent influx of Northern Hemisphere genes may negate much of this adaptation.

FERTILITY:
MINERAL & VITAMIN DEFICIENCIES

Calcium, magnesium and phosphorus have been implicated in poor reproductive performance.

This is not because of direct effects but because they are associated with low intake.

Clinical and subclinical calcium deficiency in cows around calving can result in calving problems, retained foetal membranes and poor appetite: anionic salts could be used in conjunction with other dry cow management strategies.

Supplementing a cow's diet with magnesium reduces the risk of grass tetany and also appears to reduce the incidence of milk fever through its interaction with calcium.

Phosphorus deficiency has been shown to cause delayed onset of heat in some studies but not others.

A number of micro-nutrient deficiencies are associated with impaired embryo development and poor embryo survival, with the most important being vitamin E, vitamin A, vitamin B_{12}/ cobalt and selenium.

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ADVISER ALERT

There are numerous reports of retained foetal membranes due to selenium deficiency. However, most of these studies used cattle managed under Northern Hemisphere conditions.

The effect in pasture-based diets remains ambiguous in Australian conditions.

HEIFER LIVEWEIGHT & FERTILITY

The reproductive performance of replacement heifers is directly related to liveweight at mating and calving. Calves and heifers must be reared to achieve liveweight targets, otherwise their first calving will be delayed, their liveweight at calving will be too low and their fertility during their next mating period reduced.

Well-grown heifers also produce more milk, compete better with mature cows and survive longer in the milking herd than poorly grown animals.

See Ch 22 for further details on heifer weight-for-age targets.

Nutrition is only one possible cause of poor herd reproductive performance, and often nutrition is not the most important cause of the poor performance.

Non-nutritional herd management areas identified by the InCalf project are:

- calving pattern (which is related to energy balance at mating)
- heat-detection practices
- AI technique and sire selection
- bull management
- cow health problems around calving.

For further information on these management areas, visit http://www.dairyaustralia.com.au/incalf.

Reproductive performance is affected by many factors so don't assume that nutrition will cure all reproduction problems.

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NUTRITION-RELATED COW HEALTH PROBLEMS

METABOLIC DISORDERS

Managing cow nutrition well during the dry period and in early lactation is the key to preventing or minimising the occurrence of metabolic problems.

Metabolic disorders can be clinical – when there are obvious symptoms – or sub-clinical, when there are not. Even at the sub-clinical level, they can depress feed intake and cause production losses.

Common problems include:

- milk fever
- grass tetany
- ketosis.

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Milk fever is not a disease confined to the first week or two of lactation.

If they experience a sudden disruption to calcium or magnesium uptake or absorption, cows in mid-late lactation are also at risk of going down with milk fever.

Milk fever is a gateway disease. Cows with low blood calcium levels are likely to suffer other cow health problems related to smooth muscle function or suppression of the immune system.
See Ch 21 for further details.

Milk fever (hypocalcaemia)	
Definition & physiology	Milk fever is caused by a sudden, severe decrease in blood calcium concentration (hypocalcaemia) at the onset of lactation. This is due to large increases in the demand for calcium for milk production. The incidence of milk fever increases with a cow's age and the number of previous calvings. Cow adapts to increased demands for calcium at calving by increasing the intestinal absorption of calcium and by mobilising calcium reserves held in bones. These mechanisms are activated in response to low concentrations of blood calcium, but they take some time to start working. When this process does not happen quickly enough, calcium replenishment into the bloodstream cannot keep pace with the output of calcium in milk. Once blood calcium concentration falls, muscular tremors and paralysis occur. Cows go down and may eventually die.
Link to nutrition	The key to reducing the incidence of milk fever is to stimulate the cow's mechanisms for mobilising calcium from the skeleton and increasing absorption from the intestine prior to calving, so that the cow is primed to meet the increased calcium demands after calving.
Cost of a case	$335
Management & prevention	Feed a diet during the pre-calving transition period which is: • low in calcium (0.4 to 0.6% DM) • high in magnesium (>0.45% DM) • low in phosphorus (<0.4% DM) • low in DCAD (<80 mEq kg DM). Oral calcium treatments immediately post-calving can be a useful supplementary aid in milk fever prevention for high-risk cows. They are not recommended as treatments for clinical milk fever cases.
Achievable level	1% (old cows > 8 years: 2%)
Latest thinking & references	Lean I, DeGaris P (2010) Transition Cow Management, a review for nutritional professionals, veterinarians and farm advisors. Dairy Australia.

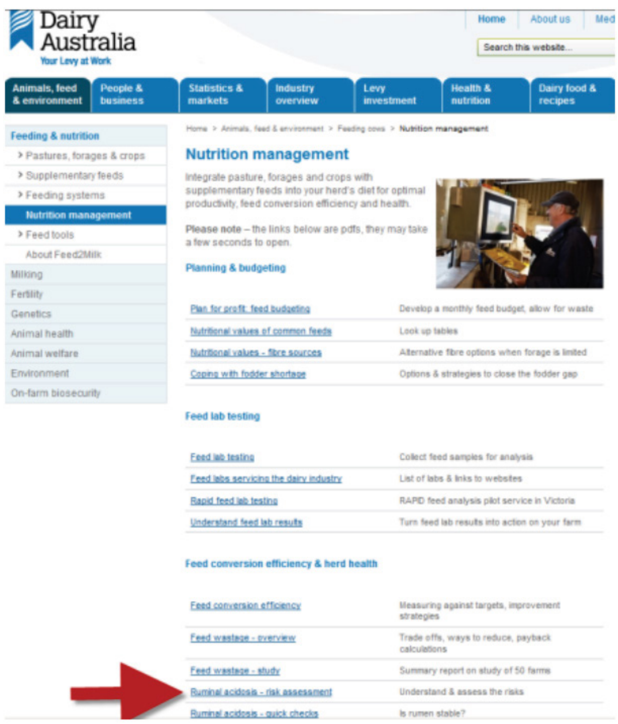
Grass tetany (hypomagnesaemia)	
Definition & physiology	Grass tetany, or grass staggers, generally occurs in lactating cows within the first few months after calving. It appears as muscular spasms and convulsions and, if left untreated, can eventually cause death. Grass tetany is associated with low magnesium levels in the blood. Since the magnesium concentration in the blood is not under hormonal control, the cow relies on a continuous daily dietary intake of magnesium to meet its needs. Magnesium also plays an important role in maintaining calcium balance and reducing the risk of milk fever, as it is critical for the release of parathyroid hormone and the production of active Vitamin D.
Link to nutrition	The key to reducing the incidence of grass tetany is to observe the following. • Supplement cows with magnesium when grazing lush, rapidly growing ryegrass-dominant pastures and feeding moderate-high levels of cereal grains that may not supply the magnesium necessary to meet the needs of a cow in early lactation. • Avoid pastures which have been top-dressed with potash (potassium) or nitrogenous fertilisers which reduce the availability of magnesium to the animal. • Avoid interruptions to feed consumption which can occur during yarding, transport or exposure to cold, wet, windy weather. If cows are not eating, they are not absorbing magnesium. • Avoid high fat levels in forages and supplements which may form insoluble magnesium salts. Magnesium is absorbed from the rumen rather than from the small intestine, so the flow rate of material out of the rumen can impact on its absorption.
Cost of a case	–
Management & prevention	Supplementation of magnesium should begin three weeks prior to calving at the beginning of the transition period. For greatest control of daily magnesium intake, magnesium supplements should be included in the pre-calving transition feed supplement. Other means of supplementing with magnesium include dusting hay or pasture with magnesium oxide, feeding a lick or block high in magnesium or feeding magnesium sulphate or chloride in drinking water. Note that putting magnesium supplements in drinking water is rendered ineffective if animals have access to alternative sources of water, such as irrigation water.
Achievable level	0%
Latest thinking & references	Lean I, DeGaris P (2010) Transition Cow Management, a review for nutritional professionals, veterinarians and farm advisors. Dairy Australia.

Ketosis	
Definition & physiology	Ketosis, or acetonaemia, is caused by a failure of metabolic mechanisms to cope with negative energy balance, as occurs in early lactation when glucose demand outstrips dietary glucose intake. Mobilisation of body fat reserves leads to circulation of fatty acids in the blood. Without sufficient glucose, they are converted in the liver into ketone bodies (mainly beta-hydroxy butyrate or BHBA) and accumulate. It is difficult to visually assess the degree of ketosis in a dairy herd. The best test for ketosis is the cow's blood BHBA concentration, with greater than 1.2 or 1.4 mmol / litre considered to be diagnostic for ketosis. Cows with BHBA levels above this threshold are at greater risk of post-calving cow health problems including displaced abomasum, reduced milk production and reproductive performance. **Primary ketosis** occurs when high-producing cows simply cannot eat enough carbohydrate to satisfy their requirements for glucose. **Secondary ketosis** can also occur when the real problem causes a cow to lose its appetite. Mastitis, milk fever and metritis can all induce this type of ketosis.
Link to nutrition	The key to reducing the incidence of ketosis is to: • not calve cows too fat • implement an effective pre-calving transition feeding program • feed high-quality forages and supplements to transition cows pre- and post-calving and do everything possible to achieve high daily feed intakes.
Cost of a case	$320
Management & prevention	To prevent ketosis, enough energy must be fed to minimise the reliance on body fat reserves in early lactation. Starchy feeds rich in rapidly fermentable carbohydrates (cereal grains) or feeding molasses can reduce the incidence of ketosis. Avoid abrupt changes in the diet which may decrease intake. Maximise nutrient intake with high-quality feed during early lactation. The initial aim of treatment is to restore the lack of glucose in the body, usually via intravenous dextrose solution. Drenching with propylene glycol or glycerine has a longer-term effect. The eventual objective however must be to ensure an ample intake of high-quality feed: energy dense and protein rich.
Achievable level	<1%
Latest thinking & references	McArt JAA, Nydam DV, Oetzel GR (2012) Dry period and parturient predictors of early lactation hyperketonemia in dairy cattle. *J. Dairy Sci.* **96**,198–209. Ospina PA, Nydam DV, Stokol T, Overton TR (2010) Association between the proportion of sampled transition cows with increased nonesterified fatty acids and ß-hydroxybutyrate and disease incidence, pregnancy rate, and milk production at the herd level. *J. Dairy Sci*. **93**, 3595–3601.

A further problem associated with ketosis in fat cows is fatty liver.

The liver is a major site of fat metabolism. Under normal conditions, a significant proportion of the nonesterified fatty acids arriving at the liver when body fat is mobilised will be completely oxidised to support the cow's energy requirements. When the rate of nonesterified fatty acid appearance in the liver exceeds all possible disposal routes, accumulation of fat in liver cells is an inevitable consequence.

Research has suggested that in such situations, fat deposition in the liver may be as much as 500 g/day during early lactation. If such rates of accumulation are maintained, total saturation will occur in about two weeks. The end result is that liver glucose production will be severely compromised.



Dairy Australia's feed.FIBRE.future project produced an extensive amount of information on acidosis.

Search for *Dairy Australia: Acidosis.*

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RUMINAL ACIDOSIS

Ruminal acidosis is increasingly a significant disorder of dairy cattle. There are two forms of the condition: lactic acidosis and subacute ruminal acidosis.

Lactic acidosis	
Definition & physiology	Lactic acidosis is the accumulation of lactic acid in the rumen, with a rumen pH <5.5.
Link to nutrition	Cows develop lactic acidosis when they eat large amounts of unaccustomed feeds rich in ruminally fermentable carbohydrates. Grain overload causes large amounts of lactic acid to be formed in the rumen. The acid is produced faster than it can be absorbed or buffered. As lactic acid builds up, rumen pH declines and microbial activity slows markedly. When the microbes slow down, fibre digestion is reduced and food intake is depressed. Cows stop eating, the rumen ceases to function and, at an extreme, a cow can die.
Cost of a case	–
Management & prevention	The key to preventing acidosis is to ensure there is plenty of saliva produced: that is, the diet must promote chewing. Cows with acidosis need to be taken off grain immediately and fed hay while being drenched with a saturated solution of sodium bicarbonate. Upon recovery, grain must be reintroduced slowly. Buffers such as sodium bicarbonate and Acid-Buf, or antibiotics such as tylosin and virginiamycin which act against lactic-acid-producing bacteria, can also help to stabilise rumen pH so that the rumen environment allows a healthy population of rumen microbes to flourish. Different cows respond differently to grain feeding. Some cows can handle 6 kg of grain/day while others will get sick on 3 kg/day. To avoid lactic acidosis, introduce grain gradually. For example, increases of 0.5 kg of grain or pellets/cow every day or so. This allows the population of rumen microbes to adjust.
Achievable level	0%
Latest thinking & References	Krause KM, Oetzel GR (2006) Understanding and preventing subacute ruminal acidosis in dairy herds: A review. *Animal Feed Science and Technology* **126**, 215–236.

Subacute ruminal acidosis (SARA)	
Definition & physiology	Subacute ruminal acidosis (SARA) is the accumulation of total VFAs in the rumen, especially propionate, with a rumen pH between 6 and 5.5. Subacute acidosis reduces feed intake, digestion of fibre, milk production, milk fat concentration and feed conversion efficiency. It can be difficult to diagnose, but chewing behaviour and the other cow signals discussed in Ch 11 can provide indications.
Link to nutrition	Subacute ruminal acidosis usually results from excessive volatile fatty acid production that exceeds the ability of the ruminal papillae to absorb them, rather than from lactic acid production. For this reason, feeding of concentrates may be the cause of subacute ruminal acidosis but it can also result when very high-quality pasture is fed.
Cost of a case	Subacute ruminal acidosis is usually of greater economic importance than lactic acidosis because a greater proportion of the herd will be affected. As it does not have as drastic an effect on individual animals, it can slip under the radar.
Management & prevention	As with lactic acidosis, strategies available to increase rumen pH include: • increasing effective fibre in diet • including a buffer in the diet • feeding grain that is more slowly degraded • ensuring even access to forages and supplements during the day.
Achievable level	0%
Latest thinking & References	Krause KM, Oetzel GR (2006) Understanding and preventing subacute ruminal acidosis in dairy herds: A review. *Animal Feed Science and Technology* **126**, 215–236.

OTHER NUTRITION-RELATED COW HEALTH PROBLEMS

There are many nutrition-related cow health problems which nutrition advisers should be aware of. These include:

- displaced abomasum
- bloat
- laminitis
- salmonellosis
- polioencephalomalacia (PEM)
- facial eczema
- plant poisonings
- trace mineral deficiencies and toxicities.

For details on each of these cow health problems, an excellent reference is the veterinary textbook 'Diseases of Cattle in Australasia' by Parkinson, Vermunt and Malmo 2010.

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FARM MANAGEMENT STRATEGIES AND NUTRITION

This chapter briefly deals with the nutritional implications of, and appropriate nutritional strategies to use for, alternative farm management strategies such as:

- extended lactations
- once a day milking
- three times a day milking
- differential bail feeding
- voluntary milking systems (AMS and AMR).

This chapter sets the scene and signposts the reader to information resources on each particular topic.

EXTENDED LACTATIONS & NUTRITION

Not all cows in the herd will be suitable candidates for extended lactations.

Extended lactations are best used as a planned approach rather than a way of managing cows that failed to get in calf in a given mating period.

Benefits

Expected benefits of extended lactations compared with the traditional 12-month seasonally calving system include:

- reduced number of days dry within the lifetime of the cow
- reduced costs per cow associated with mating, calving, animal health, and cow replacement
- a more even spread of labour requirements, input costs and income throughout the year
- improved animal well-being through reduced metabolic stress, exposure to fewer periods of high risk and increased longevity.

Cows with extended lactations generally have elevated concentrations of fat and protein during the extended component of their lactation.

System suitability

Extended lactations are best suited to pasture-based systems rather than total mixed ration systems.

Excessive body condition needs careful management for both the current season and the following season.

Persistency of milk production and maintenance of acceptable body condition are important for future selection of cows suitable for extended lactations.

At this stage, for optimum extended lactation performance, use cows with a high proportion of Northern Hemisphere genes.

Improving the overall level of nutrition does not improve extended lactation performance as measured by a decline from peak production variables and the percentage of cows milking at dry off.

Extended lactations: current research

Three recent studies in Australasia have provided information on the production of cows with lactations extending from the traditional 10 months through to 22 months: that is, one- to two-year calving interval.

2007 Ellinbank study – Auldist

Auldist et al. (2007) fed cows a minimum of 180 MJ ME/day from grazed pasture, silage, hay and grain, whilst imposing lactation lengths ranging from 10 to 22 months on cows with approximately 62% Northern Hemisphere Holstein genetics.

Although milk production on an annualised basis was negatively associated with length of lactation, much of this decline was alleviated by an increase in the solids components of the milk. It was only at 19 and 22 months of lactation that milk solids production declined (by 5 and 7% respectively). At 22 months into their lactation, the top 5% of the herd was only producing 2% less solids than the control herd.

The study also found that 95% of cows lactated for at least 16 months (that is 18-month calving interval).

For further information see:

Auldist MJ, O'Brien G, Cole D, Macmillan KL, Grainger C (2007) Effects of varying lactation length on milk production capacity of cows in pasture-based dairying systems. *Journal of Dairy Science* 90, 3234–3241.

Annualised production of cows with calving intervals ranging from 1–2 years, and their body condition change during lactation

	Lactation length (months)				
	10	13	16	19	22
Calving interval (months)	12	15	18	21	24
Annualised milk yield (kg/cow)	6454	6321	6280	5895	5775
Annualised milk solids yield (kg/cow)	497	498	495	474	463
Body condition score change (units)	0.2	0.4	0.4	1.3	0.9

Source: Auldist et al. 2007.

2007 New Zealand study – Kolver et al

In 2007 in New Zealand the study saw cows milking for 20 months on average. This study found that there was wide variation among individual cows in their ability to continue milking beyond 300 days in cows with contrasting genotypes.

North American Holstein-Friesian cows (>88% Northern Hemisphere Holstein) out-performed New Zealand Holstein-Friesians (<12% Northern Hemisphere Holstein) with extended lactations whilst gaining significantly less body condition.

Annualised milk solids reductions of 17–25% incurred by the New Zealand Holstein-Friesian cows probably reflected the lack of selection pressure for production outside a seasonal 12-month calving system. Indicative of this was a large increase in body weight and body condition score of the New Zealand cows during their extended lactation.

For further information see:

Kolver ES, Roche JR, Burke CR, Kay JK, Aspin PW (2007) Extending lactation in pasture-based dairy cows: 1. Genotype and diet effect on milk and reproduction. *Journal of Dairy Science* 90, 5518–5530.

Body condition score (BCS 10-point scale) change and ratios of annualised production relative to normal lactation production for New Zealand and North American Holstein-Friesian cows with two-year calving intervals and fed 0, 3 or 6 kg DM concentrates/day to supplement grazed pasture

	New Zealand Holstein-Friesians			North American Holstein-Friesians		
Concentrate intake	0	3	6	0	3	6
Milk yield ratio	0.75	0.79	0.71	0.85	0.93	0.88
Milk solids ratio	0.78	0.83	0.75	0.89	1.00	0.94
BCS change	2.0	2.5	3.2	0.5	0.7	1.4

Source: Kolver et al. 2007.

2009 Ellinbank Study – Grainger

This 2009 trial conducted at Ellinbank studied cows fed different diets to cows with two-year calving intervals.

Two of the diets utilised grazed pasture and concentrates at different feeding levels whereas the third diet was a high-quality total mixed ration.

This research showed that cows offered the total mixed ration had the lowest milk solids ratio (the ratio of annualised production to normal 10-month lactation production). It also showed a lower proportion of cows still milking at 600 days than cows fed pasture-based diets (71% vs. 92%). Otherwise, their results corroborated those found in the previous studies.

This experiment also provided no evidence that extending lactation has any deleterious effects on the composition or cheese-making properties of milk. On the contrary, milk from grazing cows with extended lactations was seen to have higher concentrations of solids (mostly protein, but also fat). This translated into superior coagulation properties and ultimately into higher cheese yields per 100 kg of milk. This increase in cheese yield was not associated with any compromise in cheese quality.

For further information see:

Grainger C, Auldist MJ, O'Brien G, Macmillan KL, Culley C (2009) Effect of type of diet and energy intake on milk production of Holstein-Friesian cows with extended lactations. *Journal of Dairy Science* 92, 1479–1492.

The effect of diet on annualised production variables and body condition score (BCS) change in Holstein-Friesian cows with inter-calving intervals of two years (1–8 scale)

	Control (at least 160 MJ ME/day)	High feeding (at least 180 MJ ME/day)	TMR
Annualised milk yield	4316	4591	4618
Annualised milk solids	373	407	401
Milk solids ratio (annualized : normal)	0.93	0.90	0.79
BCS change (units)	0.6	0.9	3.3

Source: Grainger et al. 2009.

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Kolver ES, Roche JR, Burke CR, Kay JK, Aspin PW (2007) Extending lactation in pasture-based dairy cows: 1. Genotype and diet effect on milk and reproduction. *Journal of Dairy Science* **90**, 5518–5530.

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MILKING FREQUENCY & NUTRITION

Milking three times a day

Cows produce more milk when milked more frequently.

The extra energy must be supplied by the diet and/or from body tissue. Diets must be well-balanced and provide sufficient nutrients for the extra production.

On average, research has shown that cows will produce almost 4 kg/day extra milk by being milked three times, rather than two times, per day. This appears to be independent of level of milk production.

Producing extra milk increases the drive of cows to eat, so if additional requirements are provided for, intake will increase.

For heavy grain feeders, milking three times a day can spread the consumption of concentrates to provide for a more stable rumen environment.

Milking three times a day may also improve udder health, resulting in lower cell counts.

With extra milk production comes a reduction in milk fat and protein concentrations. However, the total kgs of fat and protein produced per day should increase.

Milking three times a day does not have to be done all year and may be done with a fresh group of cows on a farm while a staler group of cows are milked twice per day.

Farms best suited to milking three times a day are those with:

- well-conditioned cows at a moderate to high level of production
- good milking facilities and laneways
- high levels of herd and feed management.

Most research indicates that more body condition is mobilised with increasing milking frequency. This may impact reproductive performance if increased milking frequency is undertaken in the traditional seasonal calving system without sufficient supplementation.

Milking three times per day may increase heat detection efficiency.

Some Australian dairy farmers who have tried milking three times per day have abandoned it because of difficulties managing labour. However, farmers with good access to part-time milkers to do the night shift have found that milking three times per day has actually helped them with their labour management.

Farmers considering changing from 2X to 3X milking should do a thorough cost:benefit analysis.

Milking once a day

Some farmers may find merit in reducing milking frequency to once daily:

- to reduce stress on underfed cows
- for lifestyle reasons
- for labour considerations.

The challenge is to develop farming systems that capture the full benefit of once-a-day milking, but minimise the yield loss and maximise farm profitability.

Benefits of once-daily milking include:

- increase in milk fat and protein concentrations
- reduction in the requirements for feed
- improved body condition which potentially may impact on reproductive performance.

Short-term experiments indicate an average production loss of 21% for once-daily relative to twice-daily milking. Full lactation experiments suggest greater losses, of 35–50%, but there is evidence that cows can adapt to longer milking intervals and this, coupled with increased stocking rates and care to maximise milk removal, may restrict yield losses to less than 10% on a whole-farm basis.

There seem to be breed differences in responses obtained from changes to milking frequency.

Jerseys seem to be more suited to once-daily milking whereas Holsteins may respond better to increasing the frequency.

This variable response seems to be associated with milk production potential and the relative capacity of the udders of the two types of cow.

ANOTHER POSSIBLE STRATEGY: REDUCING OR ELIMINATING THE DRY PERIOD

Traditionally, it has been considered that dairy cows require a dry period — when they are not milked — to prepare the mammary gland for the next lactation. This conclusion has been drawn using data generated using cows reaching peak milk yields of 20–30 L/day as opposed to high-producing cows that are capable of peak milk yields in excess of 50 L/day.

As milk production levels and lactation persistency have improved, milk yields at the traditional dry-off time have increased.

Cows producing more than 20–30 L/day when dried off may suffer stress associated with milk accumulation in the udder when milking abruptly ceases.

Approximately half of all new cases of mastitis occur during the dry period.

Cows are most susceptible to mammary infections in the 7–10 days following dry off.

In addition, dairy cows experience large metabolic changes when making the transition from being dry to lactating. During this period, the cow has to adapt to a sudden large increase in nutrient requirement with the onset of milk production.

The post-calving period is therefore associated with an increased risk of metabolic disorders such as fatty liver, ketosis and milk fever. Therefore, there is some logic in considering a change away from the traditional dry period if there are benefits to be gained to offset losses in milk production.

Reducing or eliminating the dry period of high-producing dairy cows may result in:

- reduction in metabolic problems post-calving
- quicker return to positive energy balance after calving
- potential improvement in reproductive performance.

Although milk production in the next lactation will be reduced by up to 25% with no planned dry period, milk protein concentration is generally increased. In contrast, the loss of subsequent production with a reduced dry period has been measured at 0–10%. Furthermore, milk will be produced from cows during the normally unproductive period of their life cycle which will help to off-set losses in the next lactation.

REDUCING OR ELIMINATING THE DRY PERIOD *continued*

The positive aspects of continuous milking include:

- less need to manipulate diets through the post calving period
- planning to milk through late gestation also avoids the stress that drying off imposes on high-producing cows.

However, management of lactating cows in late gestation could be a challenge in relation to contamination of herd milk with colostrum from individual cows near calving. It is also likely that many cows will dry themselves off spontaneously some time before calving.

Stockdale (2006) has reviewed the information on this topic, most of which has been generated in the Northern Hemisphere, so its applicability to Australian conditions still needs to be determined.

High-producing cows are generally considered to be the most likely candidates for a continuous milking strategy.

The majority of research has been undertaken with cows fed total mixed rations or complete diets and in intensively managed systems with high-producing cows, not grazed pasture as is common in Victoria.

Since many Australian dairy farmers are already milking every day of the year, if the benefits can be adequately demonstrated, a change in length of dry period, at least for some of their cows, may be a realistic and practical strategy to employ.

For further information see Stockdale CR (2006) Reducing or eliminating the dry period of dairy cows. *Australian Journal of Experimental Agriculture* **46**, 957–963.

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DIFFERENTIAL BAIL FEEDING IN THE DAIRY

Computerised bail feeding and milk monitoring technology are becoming more common in Australian dairy sheds. They enable groups of cows or individual cows to be fed varying quantities and types of concentrates per milking rather than all cows receiving the same quantity.

Parameters which may be used to differentially feed cows include breeding value for milk yield, current milk yield, days in milk, body condition score, reproductive status and parity.

Multiple feeding lines may be used to feed varying quantities of grains, protein sources, minerals and additives to different cows at each milking. Multiple feeding lines are relatively straightforward to install in rotary milking sheds but are more difficult and expensive to install in herringbone sheds.

However:

- the value proposition from individually feeding cows concentrate supplements remains unclear with few, if any, studies reporting and integrating the effects on feed conversion efficiency, the marginal milk response, body condition, health and fertility
- there are no agreed industry guidelines for how computerised bail feeding systems should be used to differentially feed cows in pasture-based production systems.

An industry study is underway to address this.

It is possible that in pasture-based production systems where pasture supply is limited and supplements are fed at a flat rate, higher genetic merit cows for milk production may experience greater nutrient deficits compared with lower genetic merit cows. Allocating higher levels of concentrates to higher genetic cows may therefore be beneficial when pasture allowance is restricted.

The position of each cow in the milking order and the time it takes it to arrive at the paddock after each milking can significantly influence the quantity and quality of pasture available to it in a pasture-based production system. Differential bail feeding could possibly help address this.

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VOLUNTARY MILKING SYSTEMS (AMS AND AMR)

While voluntary milking systems using single unit, robotic milking boxes (known as automatic milking systems or AMS) are now common around the world, their use in pasture-based production systems is relatively new.

Research undertaken at Camden as part of the Future Dairy project has been aimed at understanding how an AMS can be managed under Australian conditions.

The broad options for Australian automatic systems are:

- pasture-based system – no feed pad
- pasture-based with feed pad
- Australian-style intensive feeding.

Pasture-based system – no feed pad

If the system does not incorporate a feed pad, accurate pasture allocation is essential to ensure that the amount of available pasture is just right to encourage cows to walk out of the paddock in search of more feed within an appropriate time interval.

Overallocation and underallocation of pasture is likely to impact on milking frequency and machine-use efficiency.

Farms can be set up to offer two or three new pasture allocations each day. Experience at Camden suggests that a set-up that allows for three pasture breaks a day provides the most flexibility and can help ensure good cow traffic around the farm.

Pasture-based with feed pad

A feed pad with provision for loafing effectively acts as a third break of feed: that is, two pasture breaks plus feed pad access. However, if there is no loafing area, the feed pad will only be able to be used as a supplement to the given pasture breaks of the day.

Management of cow flow will depend on whether or not the feed pad has a loafing area associated with it.

Setting up entries and exits so cows can have access to feed pads before and after milking provides the greatest flexibility. Access to feed premilking will mean intake is not limited by how often the cow is milked.

Australian-style intensive feeding

Where the feed pad, loafing and milking units are all in the same area, cow traffic can be controlled using one-way gates placed between the feeding and loafing areas.

A well-designed intensive feeding system can allow for grazing if conditions are suitable.

All brands of AMS should have the capability for concentrate feed to be made available to cows during the milking session. Feed made available in the milking unit will act as an incentive to encourage cows in, but it is not necessary for the system to work well.

In an AMS the time available for consumption of concentrates is dictated by the milking frequency and speed of milking of each individual cow rather than the row speed or platform rotation speed in a conventional milking system. A fast-milking cow might not be able to consume the same amount of feed as a slow-milking cow.

Actual feed intake will depend on the cow's feeding rates and the total amount of time that cow spends in the unit each day. If some cows are expected to consume large volumes of concentrate on a daily basis, automatic feeders should be considered.

Automatic milking rotary (AMR)

A robotic rotary (AMR) has been developed at Camden by DeLaval engineers in consultation with Future Dairy researchers and is now commercially available.

REFERENCES:
VOLUNTARY MILKING SYSTEMS

Search for *Dairy Australia Video automatic milking systems.*

http://www.futuredairy.com.au/.

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28 NUTRITION AND DEALING WITH HEAT STRESS

Heat stress has long been a serious issue for the dairy industry in Queensland, NSW and northern Victoria. However, with shifting weather patterns and a trend towards higher temperatures associated with climate change, heat stress is emerging as an issue for herd managers in all mainland dairying regions of Australia.

IMPACTS OF HEAT STRESS ON COWS

Hot weather reduces cows' appetites and less feed means less production. Hot weather also alters the way nutrients are processed and used by the cow.

Even at 25° C, cows begin to feel uncomfortable and start actively burning energy to keep cool.

The cow must keep cool to maintain normal metabolic functions.

High temperatures increase a cow's daily maintenance energy requirements.

Hot weather reduces a cow's appetite and therefore energy intake by 10–20%.

For more information search for *Dairy Australia Cool Cows.*

ADVISER ALERT: HEAT LOAD

As a homeotherm, the dairy cow must defend its core body temperature to ensure it stays within the optimal range (38.6°C to 39.3°C). This means balancing the metabolic heat generated as a result of eating and digesting feed and the environmental heat absorbed each day with the heat lost to the external environment.

A dairy cow actively manages its body heat content (or heat load) all the time.

Heat produced internally by metabolic processes + **Heat gained from the external environment** – **Heat lost to the external environment** = **Heat load**

Heat is exchanged between the cow and its environment by radiation, conduction, convection and evaporation processes. The direction of the heat exchange depends on the temperature difference between the cow and the surrounding environment. The greater the temperature difference, the faster the flow of heat.

The upper critical temperature for a dairy cow is about 25°C. At higher ambient temperatures, the cow must actively regulate its core body temperature to maintain it in the optimal range (38.6 – 39.3°C).

About 70% of total evaporative heat loss is through sweating and 30% through respiration.

Cows are not great sweaters. They sweat at a maximum of 200mls / sq metre / hour versus the horse @ 2000 mls / sq metre / hour.

Evaporation from the cow's skin surface through sweating will increase with air movement. However, evaporation depends on a difference in relative humidity between the cow's skin and the air.

As the humidity level rises, the rate of evaporative heat loss declines. The evaporation rate is markedly increased with air movement.

Heat loss by conduction and convection gradually declines with rising ambient temperatures and ceases altogether once the air temperature reaches the cow's core body temperature. Once the air temperature exceeds the cow's body temperature, heat loss can only occur by evaporation.

These nutritional strategies for hot weather should be used to complement (but certainly not substitute for) shade and evaporative cooling. See page 28.11

NUTRITION STRATEGIES FOR HOT WEATHER

As cows eat less in the heat, the energy density of their diet should be increased by adding more starch or fat, but this adds to the risk of ruminal acidosis. The natural buffering system the cow relies on to combat ruminal acidosis does not work as well in hot weather. Keep in mind:

- aim to increase the energy density of the diet
- more starch or added fat can be useful for increasing density
- the risk of ruminal acidosis is increased during hot weather
- feeding a high-quality fibre source helps maintain a stable rumen: this still contributes energy
- for high-producing herds already being fed plenty of starch via grain / concentrates, good-quality fibre is particularly crucial
- cows prefer to eat in blocks and in the cooler times of the day
- partial mixed rations can be fed under shade between the morning and afternoon milking, allowing cows to graze pasture overnight.

Consider feeding fibre with other feeds: a mixer wagon for partial mixed rations provides flexibility of feed management.

STRATEGIES BASED ON LEVEL OF PRODUCTION

It is useful to distinguish between nutrition strategies for herds with lower and higher levels of milk production per cow:

- **up to 8,000L or 600 kg MS/cow/year**
- **more than 8,000L or 600 kg MS/cow/year**

For further information search for *Dairy Australia Cool Cows.*

Dietary fibre during hot conditions

With daily feed intake reduced and more grain/ concentrates being fed to maintain energy intake, the quality and amount of fibre sources fed is critical.

High-quality fibre can help maintain rumen stability and increase nutrient density without producing excessive metabolic heat.

Low-quality forage (high NDF) takes up too much space in the diet and makes it difficult to achieve the required daily nutrient intakes needed for milk production, given the reduced appetite.

Higher fibre intakes add safety and help cows bounce back better after an excessive heat load event has passed.

When feeding out quantities of forage fibre, ensure all cows get equal access. Heifers and less-dominant cows may be more at risk of acidosis than others.

Consider the quality of the fibre first, then decide how much fibre to feed.

Slowly fermenting starch sources

Heat-stressed cows have a greater need for glucose. Providing starch in a more slowly fermented form assists this in two ways.

First, it takes some of the starch fermentation away from the rumen. This assists the rumen to maintain feed digestibility and energy yield that can be converted to glucose in the liver. It also reduces the risk of ruminal acidosis – low rumen pH.

Second, the starch that is not digested in the rumen will normally be digested in the small intestine. At this site of digestion, it produces glucose directly for use by the gut tissue (a huge energy user in the cow) and can be transported and converted to energy for use around the body more widely. This form of digestion also releases less heat than ruminal starch digestion.

Corn (maize) grain is the most readily available slow-fermenting starch source of all the grains.

Dietary fat in hot conditions

Fat is digested and used more efficiently than starches and fibre, producing less metabolic heat and thereby adding less to heat load. However, too much fat interferes with microbial digestion in the rumen and depresses feed intake.

The best results are likely in higher-producing cows and those under greater metabolic stress.

A number of supplementary fat sources may be used, including straight vegetable oil and commercial bypass fat supplements.

It is important to manage the ratio of saturated versus unsaturated fats being fed in the diet.

In the US, diets used in hot conditions typically contain 3% fat from the main feeds in the diet, 2-3% fat from added vegetable oil, and 1-2% fat as supplementary by-pass fat.

Aim for a maximum of 6–7% total fat in the diet (DM basis).

Protein requirements in hot conditions

In hot conditions, cows still need sufficient amounts of protein in their diet to maintain rumen microbial function and supply good flows of amino acids to the intestine. However, they are faced with three challenges:

- daily feed intake is reduced
- rumen microbial function is compromised
- summer pastures are lower in protein.

Higher bypass or escape protein sources that are readily digested in the cow's small intestine can help offset lower yields of microbial protein from the rumen during hot weather.

Feed more bypass protein sources in the diet during the hot season.

Essential minerals in hot conditions

Potassium

Cows lose enormous amounts of potassium (K+) in hot conditions through sweating. Potassium bicarbonate is the preferred potassium source. Between 1.3-1.6% potassium in the diet (DM basis) is recommended during the hot season.

Sodium

In hot conditions, cows excrete more sodium (Na+) through the urine. Sodium bicarbonate is the preferred sodium but, sodium chloride (salt) is satisfactory. Approximately 0.45–0.6% sodium in the diet (DM basis) is recommended during the hot season.

Magnesium

Magnesium inputs should also be increased during the hot season, especially if you are supplementing with extra fat.

Approximately 0.35% magnesium in the diet (DM basis) is recommended. Consult your nutrition adviser.

Buffers: Are they necessary in hot conditions?

Cows normally produce large amounts of bicarbonate in their saliva (more than 2.5 kilograms per day!) which helps keep the rumen pH in the optimal range for the growth of the microbes that digest food.

Hot conditions lead to a drop in the flow and the bicarbonate concentration of cows' saliva, thereby reducing the natural buffering activity in the rumen.

In addition, the cow may be consuming less effective fibre and more grain / concentrate, so the risk of a fall in rumen pH and ruminal acidosis problems is increased.

Dietary supplementation with a buffer is good insurance during the hot season.

Recommended daily feed rates of buffers vary, depending on what is fed and how it is fed.

Useful feed additives for hot conditions

In addition to minerals and buffers, a number of other feed additives are available that have potential to assist cows in hot weather. These include:

- rumen modifiers
- yeast and yeast metabolites
- betaine
- niacin.

Rumen modifiers

Rumen modifiers such as monensin, tylosin, virginiamycin, lasalocid and bambermycin may assist by beneficially altering the balance between the different populations of microbes in the rumen and the proportions of VFAs (volatile fatty acids) they produce.

Yeast and yeast metabolites

Yeast and yeast metabolites may assist by increasing fibre digestibility and the utilisation of lactic acid, and by helping the cow produce more glucose from propionate.

Betaine

Betaine may assist in maintaining feed intake and also help by reducing the amount of energy (and glucose in particular) the cow has to burn to stay cool and carry on normal metabolic processes.

Niacin

The vitamin niacin has been shown to play a role in energy metabolism, so additional niacin supplementation may be helpful in the hot season.

ADVISER ALERT: MANAGING HIGH-PRODUCING COWS

Reduced feed intake caused by heat stress has traditionally been assumed to be primarily responsible for any decrease in milk yield.

Recent research in Arizona (Wheelock et al. 2010) suggests that heat-stressed cows change metabolism and have an increased need for glucose within their body. Feedstuffs and feeding strategies that either provide the cow with more glucose, or spare the amount used in normal body processes, may be useful in hot weather.

In this study, cows were contained in climate chambers for seven-day periods where stressed and unstressed cows were maintained on similar intakes to exclude this as a factor affecting responses.

- The greater need for glucose can be supported by providing starch in a more slowly fermented form.
- Slowly fermented forms take some of the starch fermentation away from the rumen while reducing the risk of ruminal acidosis.
- The starch that is not digested in the rumen will normally be digested in the small intestine.
- At this site of digestion, it produces glucose directly for use by the gut tissue (a huge energy user in the cow) and can be transported and converted to energy for use around the body more widely.
- This form of digestion also releases less heat than ruminal starch digestion.
- Maize grain is the most readily available slow-fermenting starch source.

This research clearly demonstrated that a lowered nutritional plane accounted for only about 50% of the reduction in milk synthesis during heat stress, and that shifts in post-absorptive metabolism may be responsible for a large proportion of the remainder. The heat-stressed lactating cows experienced a variety of post-absorptive metabolic changes that were not typical of an animal on a lowered nutritional plane.

ADVISER ALERT CONTINUED ...

With regard to lipid and carbohydrate metabolism, this is primarily characterised by:

- the lack of adipose tissue mobilisation
- increased basal and stimulated insulin release
- an increase in glucose disposal.

Glucose becomes a favoured fuel for heat-stressed animals. Despite a reduced DM intake and an increased negative energy balance, cows in heat stress conditions did not have an increase in plasma nonesterified fatty acids, but they had an increase in blood insulin levels (and insulin is a potent anti-lipolytic hormone).

The lack of a nonesterified fatty acid response presumably indicates a reduction in fatty acid oxidation during heat stress. If there is a preferential need to oxidise glucose during hyperthermia, then preventing adipose tissue mobilisation and thus substrate competition is one logical mechanism by which this is accomplished. Collectively, minimising tissue mobilisation allows for both maximum glucose utilisation and hepatic glucose output.

Feeding fat in hot conditions can be an advantage. It is digested and utilised by the cow more efficiently than starches and fibre, producing less metabolic heat and thereby adding less to the heat load.

However, too much fat interferes with microbial digestion in the rumen, depresses feed intake and can lower milk fat synthesis in the udder, leading to lower milk fat production.

In the US, diets used in hot conditions typically contain 3% fat from the main feeds in the diet, 2–3% fat from added vegetable oil and 1–2% fat as supplementary by-pass fat.

Recent research studies conducted overseas indicate that hot weather can have negative impacts on dry cows as well as milking cows, affecting the dry cow's placenta and her developing udder. This can lead to reduced calf birth weights and viability, and reduced milk production in the next lactation. So farmers with autumn calvers should consider how much paddock shade is available for their cows over the hot summer months when they are dry.

COOLING STRATEGIES

There are two cooling strategies which can be used to help minimise heat stress:

- minimise heat gain with shade
- maximise heat loss with evaporative cooling.

Minimising heat gain with shade

Minimising heat gain is achieved by reducing direct solar radiant heat load through shade, particularly during the hottest part of the day.

Cows should ideally have 4 m^2 of shade available to them at midday. Shade options include:

- natural shade from trees
- portable paddock shade structures
- permanent shade structures (placed over the dairy holding yard or combined with a feed-out facility with a compacted gravel or concrete surface). These have the advantage that they provide passive cooling: that is, they do not require energy to operate.

Shade over the dairy holding yard is of greatest benefit if cows are free to go to / from a feed pad nearby. Feed and water should ideally be provided within 15–20 metres of shade, otherwise cows may not be willing to move between them.

Shade structures may incorporate shade cloth or a fixed roof. The capital cost of a shade cloth structure is considerably less than a fixed roof structure but it has a shorter lifespan (for example, 10 years versus 25+ years). Shade structures and any associated feeding facilities should be professionally designed and built according to local building codes and regulations.

There are a number of specific design details for each shade infrastructure option that make the difference between a structure that works very well and one that cows and the farmer don't like to use.

The ultimate aim of any shade structure is to optimise feed intake.

Maximising heat loss with evaporative cooling

The cheapest and easiest option is to install a set of sprinklers over the dairy holding yard and wet cows to the skin for 30–60 minutes prior to milking on hot days. The hotter the cows, the longer the cooling time.

Only about half of Australian dairy farms have a sprinkler system in their dairy yard. Many of these sprinkler systems are suboptimal. An ideal system should have sufficient sprinklers to cover the entire dairy holding yard in still or windy conditions and apply medium-large water droplets on cows from above. It should have a timer installed to enable an on / off cycle every 10–15 minutes to conserve water and a spray curtain installed at the entry to the dairy shed. Cows' teats should be dry when the cups are put on (dry them with paper towel if necessary). Avoid wetting cows after milking while teat orifices are still open.

If cows are kept in the dairy holding yard on hot days for several hours under sprinklers prior to afternoon milking, they must be given access to drinking water via a trough at the back or along the side of the yard.

Cooling with water will not be effective unless there is some air movement. Increasing air flow over the cow's skin surface from 0 to 1.0 m/sec increases evaporative heat loss three-fold. Cows should therefore not be packed too tightly in the dairy yard.

Fans should also be considered for dairy yards / shade sheds (especially for higher production herds which are more susceptible to heat) and are very good insurance against extreme heat wave events in which there is little / no breeze. Sufficient fans to cover the whole area are needed, placed high and directed downwards over the cows. Fans that are too low and may get wet from sprinklers are less effective and are an OH&S risk. Fans alone (without sprinklers) are counterproductive once the air temperature exceeds the cow's core body temperature.

Shade without sprinklers has been shown to be more effective than sprinklers without shade.

Other strategies to help keep cows cool

In addition to shade and evaporative cooling, there are a number of other strategies that farmers can use during the hot season to help keep cows cool. These include:

- changes to milking time
- access to cool drinking water at all times
- changes to paddock rotation
- altering mating management.

A total systems rethink will give the best chance of getting through the hot season with minimal impact on finances and cows' health and fertility.

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