Feeding Dairy Cows

A manual for use in the Target 10 Nutrition Program

Edited by Joe Jacobs with Ann Hargreaves

Third Edition
Acknowledgments

This manual, *Feeding Dairy Cows*, is a resource manual for use when Target 10 delivers its program on dairy cow nutrition. The manual makes use of information from previously produced nutrition manuals:

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


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Foreword

The Target 10 Project’s original objective was to focus effort on achieving improved farm profitability through increased pasture consumption. However, during extension in this area, it became apparent that other issues of major concern to farmers should be addressed as well.

Julian Benson

Dairy cow nutrition, identified as one of these concerns, is now a major component of the Target 10 three-year plan; and the Nutrition Program is being offered across the State.

The Target 10 Nutrition Program began in 1997. It comprises theory as well as practical on-farm problem solving and, when necessary, one-to-one consultation.

The season since the program began has been very challenging. People who completed the course would have benefited greatly from the knowledge gained about balancing diets, and basing purchase of feeds and forages on the nutritional value of the feeds, as well as being reminded that pasture is still our cheapest and most valuable feed source.

Feeding dairy cows profitably is an issue of paramount importance to all dairy farmers. The Target 10 Nutrition Program encourages farmers to maximise their pasture consumption, and then to address feed gaps as efficiently and effectively as possible by using supplements.

This revised manual documents the direction and the content of the Target 10 Nutrition Program. It aims to provide a worthwhile source of information for farmers to use during their participation in the program. And when the program is over, the manual will serve as a permanent source of reference material.
The manual has been compiled by many people – staff from the Department of Natural Resources and Environment, the University of Melbourne, dairy and feed companies, and private veterinary practitioners. These individuals from across industry sectors, in partnership, will continue to deliver extension activities on this topic.

Pivotal to the development of the program has been the input from the farmers who provided advice and guidance on both the program and manual. I would like to thank them all for their help.

To every one who attends the program, I hope that you will find it is Information that works.

Julian Benson
Chair
South West Target 10 Nutrition Working Group
Getting Started in Cow Nutrition

This chapter . . .
Introduces some basic concepts in the nutrition of dairy cows and the terminology that you will encounter throughout the manual.

The main points in this chapter . . .

• Cows are ruminants

• The stomach of the cow has four chambers, the largest of which is the rumen

• Cows are well adapted to a herbage diet

• Cows need water, energy, protein, fibre, vitamins and minerals in their diet.
**What’s in Feeds?**

This chapter explains. . .
The important constituents of feed for dairy cows, how the constituents are measured and their sources in the diet.

The main points in this chapter. . .

- Dry matter (DM %) is the feed remaining after all the water has been removed. All other components of feed are expressed as a proportion of dry matter.

- Digestibility (%) is the proportion of a feed which is not excreted as manure. It is one indicator of feed quality.

- Metabolisable energy (ME) is the energy available from feed and used by the cow for maintenance, activity, milk production, pregnancy and weight gain.

- Crude protein (CP %) includes both true protein (made up of amino acids) and non-protein nitrogen (NPN) which rumen microbes convert into protein.

- Neutral detergent fibre (% NDF) is a measure of dietary fibre. It includes indigestible and digestible fibre.
The main points in this chapter...  

- Cows rely on rumen microbes to convert feed components into usable sources of energy and protein  
- Fibre maintains gut movement and stimulates rumination (chewing the cud)  
- Speed of digestion depends on the size of feed particles, digestibility of feed and level of intake  
- A healthy microbial population is essential for proper rumen function and feed utilisation  
- Growth and multiplication of microbes depends on rumen pH and the supply of energy and protein  
- Rumen microbes ferment carbohydrates to make volatile fatty acids (VFA) and gases  
- VFAs are the major source of energy for the cow  
- The amount of each VFA produced depends on the diet  
- Milkfat test is affected by the relative amounts of the different VFAs  
- Rumen degradable protein (RDP) and non-protein nitrogen (NPN) are broken down in the rumen to amino acids and ammonia  
- Rumen microbes use amino acids and ammonia to build more microbes  
- Microbes are flushed out of the rumen and digested and absorbed in the small intestine. This ‘microbial protein’ supplies most of the cow’s protein  
- Dietary protein not broken down in the rumen is also digested and absorbed in the small intestine  
- Most fats are digested in the small intestine.
Nutrient Requirements of Dairy Cows

This chapter explains. . .
The specific nutritional needs of your cows and how to calculate a cow’s energy requirements for its major metabolic activities – maintenance, activity, milk production, pregnancy and gain in body condition.

The main points in this chapter. . .

• Energy requirements change according to cow size, activity, stage of pregnancy and level of milk production

• Protein requirements vary with stage of lactation and whether milking or dry

• Microbial protein can sustain production of up to 12 L per day. Up to this level of production, all protein in the diet can be rumen degradable protein (RDP). Beyond this, undegradable protein (UDP) requirements rise as production increases

• Good quality pasture contains both RDP and UDP. Cows grazing ryegrass/clover pasture and producing up to 30 L per day are unlikely to need supplementary UDP

• The absolute minimum amount of fibre in the diet is 30 per cent neutral detergent fibre (NDF). The minimum crude fibre content is 17 per cent.

Later in the program you will need to refer to much of the information presented in this section. For ease of reference, this information has been tabulated in Appendix C.
This chapter explains. . .
The changes in energy requirements and intake capacity in early lactation, as well as how to calculate a cow’s energy requirements and decide what percentage of protein and fibre should be in the diet, when given details of her size, activity, stage of pregnancy and lactation, and change in liveweight.

The main point in this chapter. . .
- The partitioning of energy to milk production and body condition changes with the stage of lactation.
This chapter explains. . .
The factors that affect how much pasture a cow will eat, what is meant by pasture quality and how it changes with season, species composition and maturity of the sward.

The main points in this chapter. . .

- Nutrient intake from pasture is affected by: the cow’s grazing behaviour, the allocation of pasture, the quality and palatability of pasture and the cow’s ability to graze selectively

- When cows are offered more pasture, their intake increases but they utilise less of the available pasture. Each additional kilogram of dry matter intake requires more and more pasture to be offered

- Higher quality pastures allow greater intakes to be achieved as well as providing more nutrient per kilogram. Quality has a ‘multiplying’ effect on the cow’s consumption of nutrients

- By grazing selectively, cows eat pasture with 3–4 per cent more protein and 0.5–1.0 MJ/kg more metabolisable energy than the average diet available from a pasture. As pasture allocation increases, cows become more selective.
Best Use of Pastures

This chapter explains . . .
How to allocate pasture and how to calculate the amount of feed provided by the allocated area.

The main points in this chapter . . .

- To optimise the quality, availability and regrowth of pasture it is important to maintain a ‘pasture wedge’ across the farm, where all pasture is in the range 1300–2200 kg DM/ha

- Pasture should be grazed at 2200 kg DM/ha (10–15 cm high)

- After grazing, 1300 kg DM/ha (3–4 cm high) should remain

- Length of the grazing rotation depends on the pasture allocation

- The area allocated depends on the growth rate of pasture and must be adjusted when growth rate changes

- This method of allocating pasture will maintain the ‘pasture wedge’

- Constant monitoring of pasture growth is important for optimising pasture growth and quality.
This chapter explains... Nutritional and practical issues to consider when choosing a supplement and details of the nutrient composition of feeds.

Whether to feed supplements, and which ones, are decided on a seasonal basis (as part of annual feed planning) as well as day-to-day (balancing feed demand against current pasture growth and cover).

The main points in this chapter...  
- Factors to consider when deciding on which supplements to use  
  - What is the limiting nutrient in the diet?  
  - Which supplements are available and what is their nutrient composition?  
  - What are the relative costs of supplements?  
  - What are the practical considerations?  
  - How will a supplement affect the balance of the diet?  
- Feeds can be classified as energy supplements, protein supplements, roughages (such as hay and silage) and fodder crops  
- Tables of feed composition show the wide variation in energy and protein content in feeds  
- Estimates of nutrient supply in the diet are only as good as the information available about the ingredients of the diet.  
- Practical considerations to take into account when feeding concentrates, turnips, hay and silage  
- High supplement use may involve increased capital investment, more exposure to fluctuations in the cost of purchased feed and increased labour requirements.
**Effects of Supplements on Pasture Intake**

This chapter explains . . .
How to weigh up the benefits and costs of supplementary feeding.

The main points in this chapter. . .

- **Pasture substitution** is the decrease in pasture intake when cows are fed supplements.
  - Substitution is greatest when cows have plenty of high quality pasture and are also fed concentrates.
  - There is less substitution when pasture intake is lower.

- **Pasture monitoring** can detect whether substitution is causing a decline in pasture utilisation and therefore whether supplements are being used effectively.

- Supplements can affect milk production, cow condition or pasture availability. The effect on milk production may not be immediate.

- Milk responses to supplementary feeding depend on stage of lactation, the amount and quality of pasture, amount and quality of supplement, cow condition, and level of production.

- Supplement use is most profitable when it increases the utilisation of pasture.

- Using supplements strategically when pasture supply is limited, may improve pasture utilisation by sustaining herds that are large enough to make the most of periods of pasture surplus.

- Supplements can also be used to sustain longer lactations, increase cow production and improve pasture utilisation.

- The profitability of supplementary feeding depends on the cost of supplements and the benefits of supplementary feeding.
  - Feed planning is important, especially at higher stocking rates.
Formulating a Diet

This chapter explains . . .
How to formulate a basic balanced diet that takes account of production goals.

The main points in this chapter. . .

• Diet formulation involves matching the feed supplied with the specific requirements of the herd in the most cost-effective way

• Diet formulation should be viewed in conjunction with pasture feed planning

• In order to provide the nutrients calculated as being required, it is important to know how much feed a cow is capable of eating

• Intake capacity depends primarily on size and weight of the cow, digestibility of feed on offer and stage of lactation

• Supplements should be compared by comparing the cost of the nutrients they contain

• Unbalanced diets may lead to metabolic disorders.
Diet and its Effect on Milk Production and Body Condition

This chapter explains:
How level of feeding and composition of the diet affect volume and composition of milk.

The main points in this chapter...

- Cows should be in at least condition score 5 when they calve
- Because of their limited rumen capacity, cows in early lactation require feed to be top quality
- High levels of feeding in early lactation will not make up for poor condition at calving. It is important to feed cows well in early lactation approaching peak lactation and peak intake
- Cows put on condition more efficiently in late lactation when they are still milking, rather than when they are dry
- Cows close to calving and in early lactation need high quality diets with adequate supplies of energy, protein and fibre. It is important to avoid abrupt changes to the diet
- Diet has considerable influence on the fat and protein content of milk, but relatively little effect on its lactose content
- Milkfat test falls when the diet is low in fibre
- High energy, starch-based diets increase lactose production, milk volume and milk protein production simultaneously.
Nutrition and Fertility

**This chapter explains . . .**
The impact of nutrition on the reproductive performance of the dairy herd.

**The main points in this chapter. . .**

- How to calculate submission rate and conception rate and use them to describe a herd’s reproductive performance
- Nutrition is only one of many factors that affect reproduction
- The impact of the calving pattern on subsequent reproductive performance
- Low energy intakes in early lactation can delay the first detected heat and depress the rates of submission and conception
- Cows will inevitably be in negative energy balance in early lactation, but good reproductive performance depends on cows:
  - Calving in good condition (score 5 to 6)
  - Not suffering too severe a drop in appetite after calving
  - Not losing too much condition in early lactation.
This chapter explains. . .
The nutritional needs of heifers in the three phases of their development – the milk-fed calf, the weaned calf and the yearling.

The main points in this chapter. . .

• A system of heifer rearing should produce healthy animals that are able to grow to target liveweight with minimum input costs

• It is essential that calves consume at least 4 litres of high quality colostrum in their first six hours of life. Calves must be hand-fed colostrum if they cannot suckle

• Calves should be fed to promote rumen development

• Calves can be weaned at six weeks if they are eating at least 0.75 kg concentrates per day

• Calves cannot eat enough pasture to sustain good growth rates. Pasture is not a suitable feed for milk-fed calves and pasture-only diets should be avoided until calves reach 200 kg liveweight

• Good heifer growth rates are important for milk production and fertility and to minimise calving difficulties. Growth rate in Friesians after weaning should average 0.7 kg/day

• Growth should be monitored regularly (preferably by weighing) to ensure that targets are being met

• Pasture should be top quality (at least 11 MJ/kg DM) if it is used as the sole food for heifers less than 12 months of age

• Pasture should be supplemented with concentrates when heifer growth rate falls below 0.5 kg/day

• Heifers eating pasture-based diets are unlikely to be at risk of fatty udder syndrome.
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1. **Introduction**

The major profit driver for Victorian dairy farming is the direct conversion of high-quality pastures to milk.

Target 10 has conducted many programs with the aim of increasing pasture consumption on dairy farms. Many of you would have been involved in these pasture programs, where grazing management (in particular, maintaining a ‘pasture wedge’) is the main issue.

Good grazing management will help to grow more pasture and to make better use of what is grown. To use their pasture more efficiently, many Victorian farmers have increased stocking rates. As well, the strategic use of bought-in feed supplements the pasture grown on the farm.

Fodder crops and irrigation can also play a part in the drive to increase profitability through better utilisation of pasture.

The increasing use of supplementary feeds has led to greater interest in cow nutrition and questions about what cows require and how best to meet their requirements.

Advice on feeding strategies and products may often seem confusing and contradictory. Unfortunately, no simple answer, or single ‘recipe’, for feeding cows will suit everyone.

Cow nutrition might seem complex. But the basic aim is to ascertain what cows require and how best to meet their needs in a cost-effective and practical way.

All feeds come under consideration: pasture, silage, hay, fodder crops, grains, pellets and by-products, as well as trace elements and mineral premixes.

The challenge of nutrition in a pasture-based system is that the major component of the diet, the pasture, varies from day to day, from paddock to paddock and even within paddocks. As well, cows graze selectively from the pasture they are offered.
Pasture generally makes up 70 per cent or more of cows’ diet, so the challenge is to understand and manage this variation in pasture and to be able to balance the cows’ diet with other suitable feeds.

1.1 Aims of the Target 10 Nutrition Program

At the end of this program, you will be able to calculate and provide your dairy herds with cost-effective feeds that match your farming system and plans.

Formulation of diets will be based on using pastures first, then supplements.

Extension will reinforce understanding of dairy cow nutritive requirements, the benefits and drawbacks of various feed components as well as the calculation of optimal diet balance.

These goals were negotiated with Target 10 farmer committees working on the development of the Nutrition Program.

1.2 Objectives of the Target 10 Nutrition Program

By the end of this program, you will:

- Understand the nutritional requirements of cows and be able to express them in terms of energy, protein and fibre
- Be able to compare feeds on the basis of their nutritive value
- Understand more about the impact of nutrition on milk production, health and reproduction
- Be able to check whether a diet is balanced in terms of energy, protein and fibre
- Have an understanding of how pasture and feed supplements interact, including the factors that affect responses to supplements and how they determine the profitability of supplementary feeding.

This program involves both theory and practical on-farm problem solving.
One-to-one advice is also available to participants in the Target 10 Nutrition Program.

1.3 Program Outline

The program will cover:

- Key points in cow nutrition
- What is in feeds
- Rumen function
- Feed requirements of the cow
- Nutrient intake from grazed pastures
- The effect of supplement use on pasture intake
- Formulating a diet
- The effect of diet on production and body condition
- Nutrition and reproduction
- Nutrition and dairy replacements
- Case studies.
2. Getting Started in Cow Nutrition

2.1 Cows are ruminants

Cows are herbivores and have a digestive system that is well adapted to a herbage-based diet. Cows belong to a group of mammals known as ruminants. Ruminants have a complex digestive system which is characterised by a four-chambered stomach. The largest of these chambers is the rumen.

The gastro-intestinal system of ruminants enables them to digest plant material in a way that non-ruminant mammals with single stomachs, such as pigs, dogs or humans, cannot.

The rumen contains large numbers and many types of micro-organisms (often referred to as microbes). These microbes feed on plant material eaten by the cow and produce end products that are made use of by the cow, and also by the microbes for their own multiplication and cell growth.

The microbes themselves are digested further along the digestive tract.

The nature of the cow’s digestive system largely determines which components of her diet are important.

The purpose of dairy cows is milk production, so their diet must allow them to fulfil the functions of lactating, and of reproducing annually.

2.2 Nutrients dairy cows need

The nutrients required by dairy cows are water, energy, protein, fibre, vitamins and minerals. These requirements largely determine how we think about the composition of their feed.

Feed contains both water and dry matter. The dry matter component of the diet is the part which contains the
necessary energy, protein, fibre, minerals and vitamins. The components of the feed are outlined in Figure 2.1.

![Figure 2.1: The major components of feed.](image)

### 2.2.1 Water

The body of a dairy cow is composed of 70–75 per cent water. Milk is about 87 per cent water. Water is also essential to regulate body temperature. As well, water is involved in digestion, nutrient transfer, metabolism and waste removal.

Water has structural and functional roles in all cells and all body fluids. An abundant, continuous, and clean source of drinking water is vital for dairy cows.

### 2.2.2 Energy

A dairy cow uses energy to function (walk, graze, breathe, lactate, and maintain a pregnancy). Energy is the key requirement of dairy cows for milk production. It determines milk yield, milk composition (fat and protein content) and body weight.

### 2.2.3 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.

Proteins are made up of various amino acid molecules. Amino acids are the building blocks for the production of protein for milk, tissue growth and the development of the foetus during pregnancy.
Cows require 25 different amino acids for normal metabolic functioning. Fifteen of these can be produced by the cow’s own metabolism. The remaining ten are termed essential amino acids because they must either be supplied in the diet (as dietary protein) or as a product of the digestion of the microbes in the rumen (microbial protein).

Protein is usually measured as crude protein. Terms like rumen degradable protein (RDP) and undegradable dietary protein (UDP) or bypass protein are also coming into use. The terms are explained more fully in Chapter 3.

2.2.4 Fibre

Cows need a certain amount of fibre for efficient rumen function. The fibre is required to ensure that the cow chews its cud (ruminates) enough and therefore salivates. The saliva helps to buffer the rumen pH and prevent the degree of acidity varying too much.

The length and the structure of the fibre are both important. They determine how much chewing a feed requires. Feeds which need extra chewing increase the flow of saliva.

Fibre in the cow’s diet also slows down the flow of material through the rumen and thus gives the microbes more chance to digest feed.

Products of fibre digestion are important for the production of milk fat.

2.2.5 Vitamins and minerals

Vitamins are organic compounds that all animals require in very small amounts.

At least fifteen vitamins are essential for animals. Vitamins are needed for many metabolic processes in the body; e.g. for production of enzymes, bone formation, milk production, reproduction and disease resistance.

Minerals are inorganic elements. They are needed for (among other things) teeth and bone formation; enzyme, nerve, cartilage and muscle function or formation; milk production; blood coagulation; energy transfer; carbohydrate metabolism; and protein production.
3. **What’s in Feeds?**

3.1 **Dry matter**

Dry matter (DM) is the portion of the feed remaining after all the water has been taken out. The dry matter part of a feed contains the nutrients: energy, protein, fibre, vitamins and minerals.

Dry matter is measured by weighing samples of feed before and after they have been dried at 100°C. The proportion of dry matter in a feed is expressed as a percentage of the wet feed (%DM).

Different feeds contain different proportions of dry matter and water (see Figure 3.1 and Table 3.1).

![Figure 3.1: Dry matter and moisture content of some typical feeds.](image)
### Table 3.1: The approximate dry matter and moisture content of some typical feeds.

<table>
<thead>
<tr>
<th>Dry Matter (%)</th>
<th>Moisture (%)</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>←Water</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>←Short, leafy pasture</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>70</td>
<td>←Pit silage</td>
</tr>
<tr>
<td>40</td>
<td>60</td>
<td>←Long, stemmy pasture</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>←Baled silage</td>
</tr>
<tr>
<td>60</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>20</td>
<td>←Hay</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>←Wheat grain</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

It is important to be able to work out the amount of dry matter (in kg) that cows consume from the total amount of feed 'as fed' (which includes dry matter and water).

### EXERCISE 3.1 How much dry matter is in a feed?

Calculate and fill in the last two columns of the following table.

(Answers to all the exercises are in Appendix A.)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of feed</td>
<td>Feed as-fed (kg)</td>
<td>Moisture (%)</td>
<td>Dry matter (%)</td>
<td>Dry matter (kg)</td>
</tr>
<tr>
<td></td>
<td>100 - B</td>
<td>A x C ÷ 100</td>
<td>100 - B</td>
<td>A x C ÷ 100</td>
</tr>
<tr>
<td>Pasture</td>
<td>88</td>
<td>83</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Silage</td>
<td>50</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>16.7</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATION EXAMPLE:** To calculate the dry matter percentage (per cent DM; column C), subtract the moisture per cent (column B) from 100 per cent. For example, for pasture:

\[100 - 83 = 17.\]
To calculate weight of DM in kg (column D), multiply the number of kg as-fed (column A) by the dry matter per cent (column C). To continue the pasture example:

\[ 88 \times \left( \frac{17}{100} \right) = 15 \text{ kg DM} \]

### 3.2 Energy

The energy in feed is a measure of that feed’s ability to help the cow function and be productive. All feeds have a gross energy value (see Figure 3.2).

Some of the gross energy is lost in the faeces. The energy that is absorbed by the cow is termed digestible energy. From the digestible energy, further energy losses occur in the production of urine, as well as digestive heat and gas.

All the remaining energy is known as metabolisable energy (ME).

![Energy Diagram](image)

**Figure 3.2:** The flow and partitioning of dietary energy through the cow.

Megajoules are used to measure energy content. The main thing you need to remember is the higher the value in megajoules, the better the quality of the feed.

The ME is the energy available for use by the cow: it is the energy used for maintenance of body systems, activity, milk production, pregnancy and weight gain.
3.2.1 How energy is measured

Two measures of energy are digestibility and metabolisable energy.

**Digestibility**

Digestibility relates to the portion of food which is not excreted in the faeces and so is available for use by the cow.

Digestibility is not a direct measure of energy, but it does indicate overall feed quality. Because she is able to digest and use more of it, the greater the digestibility, the greater the benefit of that food to the animal.

The higher the digestibility, the higher the metabolisable energy.

Digestibility is commonly measured as a percentage. A pasture with a digestibility of 50 per cent, for example, means that only half of the feed eaten will actually be of use to the animal. The other half will be immediately excreted in the faeces.

**Metabolisable energy**

Some of the energy released by digestion is not used by the cow. It is belched out as methane and carbon dioxide, or passed out in the urine or lost as heat created during rumen fermentation (see Figure 3.2).

The energy in a feed that a cow can actually use for its metabolic activities (i.e. maintenance, activity, pregnancy, milk production, and gain in body condition) is called metabolisable energy.

As already outlined, the energy content of a feed is calculated from its digestibility.

The energy content of a feed (also called its energy density) is measured as megajoules of metabolisable energy per kg of dry matter (MJ ME/kg DM).

Throughout this manual, references to cows' energy requirements and the energy density of feeds will be given in megajoules of metabolisable energy (MJ ME).

The higher the energy content of a feed, the more energy there is available to the animal.
If a feed contains 12 MJ/kg DM, then each kg of dry matter of that feed contains 12 megajoules of metabolisable energy 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.

3.2.2 Types of energy

Energy can come from various parts of the feed. Carbohydrates, fats and oils, and even protein can provide energy.

Carbohydrates

Plant tissue dry matter is about 75 per cent carbohydrates. Carbohydrates are the main source of energy for the grazing cow.

Sugar molecules of various types are the building blocks of carbohydrates. The sugars are chemically bound together in different numbers and in a variety of ways to form the three types of carbohydrate: soluble, storage and structural.

Soluble carbohydrates are the simple or individual sugars found in the cells of growing plants. They are digested and used almost instantly by the microbes in the rumen.

Soluble carbohydrates are digested 100 times faster than storage carbohydrates. Soluble carbohydrates are found more in leaf than in stem.

Storage carbohydrates are made up of sugar sub-units which are chemically bound together and are found inside plant cells.

Starch is an example of a storage carbohydrate. Storage carbohydrates are digested about five times faster than structural carbohydrates. Storage carbohydrates are found in grains, leaf and stem and in the bulbous roots of fodder crops.

Structural carbohydrates are fibrous components of plant cell walls. They provide the structural support that plants need to grow upright. Pectin, hemicellulose, and cellulose are all structural carbohydrates. Large amounts of structural carbohydrate are found in stemmy pasture and straw.
Lignin and silica are often associated with structural carbohydrates in plants. They give structural support to plants but are indigestible and are not actually carbohydrates. They can bind to the structural carbohydrates and make them less digestible.

**Fats and oils**

Only 2–3 per cent of pasture dry matter is fat or oil. Fats and oils include vegetable oils, tallow (animal fat), and processed fats. No more than 5 per cent of a cow’s total intake of dietary dry matter should be fats. Fats can decrease the palatability of the diet and can coat the fibre, interfering with its digestion by rumen microbes.

**Protein**

A surplus of protein in the rumen can be used by the rumen microbes for energy. This is, however, an inefficient use of protein.

---

**EXERCISE 3.2 Energy intake from various feeds.**

*In the following table, which cow is eating the most energy? (Answers to all the exercises are in Appendix A.)*

<table>
<thead>
<tr>
<th>Cow</th>
<th>Type of feed</th>
<th>Intake (kg DM)</th>
<th>Energy content (MJ/kg DM)</th>
<th>Energy intake (MJ) A x B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amy</td>
<td>Pasture</td>
<td>15</td>
<td>11</td>
<td>165</td>
</tr>
<tr>
<td>Bossy</td>
<td>Silage</td>
<td>15</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Chloe</td>
<td>Hay</td>
<td>10</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>Deidre</td>
<td>Wheat</td>
<td>8</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATION EXAMPLE:** Amy eats 15 kg DM of pasture. Each kg contains 11 MJ of energy. Her total energy intake is:

\[
15 \text{ kg DM} \times 11 \text{ MJ/kg DM} = 165 \text{ MJ}
\]
3.2.3 Energy and milk production

Table 3.2 shows two cows, one producing 20 litres and the other 30 litres. The second column shows the amount of energy each cow needs to eat each day to produce that amount of milk.

Table 3.2: Cows fed diets of different energy density and producing at two levels of milk production: amounts of dry matter required daily.

<table>
<thead>
<tr>
<th>Milk yield (L/day)</th>
<th>Energy requirement (MJ/kg DM)</th>
<th>Required intake (kg DM/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 MJ/kg DM</td>
</tr>
<tr>
<td>20</td>
<td>168</td>
<td>16.8</td>
</tr>
<tr>
<td>30</td>
<td>220</td>
<td>22.0</td>
</tr>
</tbody>
</table>

(Source: Stockdale, 1991)

The dairy farmer has two feeds available to give to the cows:

- silage, with an energy density of 10 MJ/kg DM, and
- green, leafy pasture, with an energy density of 12 MJ/kg DM.

To produce more milk, a cow must eat more dry matter. If lower quality (i.e. lower energy density) feed is provided, the cow must eat a greater amount of it.

To produce 30 litres of milk on the 10 MJ/kg DM diet a cow must eat 22 kilograms of dry matter daily – a very large amount.

Some dairy farmers say you cannot ‘milk from silage’, no matter how much you give them. Others say you can.

Both are right: it depends mainly on the energy content of the silage. It is difficult for a cow to get enough energy to milk well from silage with an energy density of only 8 MJ/kg DM. However, it is possible to make silage measuring 11 MJ/kg DM, from which cows could milk.
EXERCISE 3.3: Energy content of feeds and milk production.

What does the energy content of the feed need to be to reach the milk production target? Write your answers in the last column of the following table.
(Answers to the exercises are in Appendix A.)

<table>
<thead>
<tr>
<th>Cow</th>
<th>Target milk yield (L/day)</th>
<th>Estimated energy required (MJ/day)</th>
<th>Possible intake (kg DM/day)</th>
<th>Required energy content of feed (MJ/kg DM) (A ÷ B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>170</td>
<td>15</td>
<td>11.3</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>186</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>198</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Protein

3.3.1 Types of protein

**Crude protein**

Dietary protein is commonly termed ‘crude protein’. This can be misleading, because crude protein percentage (CP%) is not measured directly but is calculated from the amount of nitrogen (N) in a feed:

\[
\text{Crude protein (\%) = nitrogen content (\%) x 6.25}
\]

Some of the nitrogen is in protein (‘true protein’). But there are also other sources of nitrogen. The other nitrogen sources are called ‘non-protein nitrogen’ (NPN). Therefore crude protein can also be expressed as:

\[
\text{Crude protein = true dietary protein + non-protein nitrogen}
\]

The microbes in the rumen are able to convert non-protein nitrogen into true protein if sufficient energy is available to them. Because of this, both sources of nitrogen can be used as protein source by the cow. The components of crude protein are shown in Figure 3.3.
Chapter 3. What’s in Feeds?

Non-protein nitrogen

Non-protein nitrogen (NPN) is not actually protein, it is simple nitrogen. Rumen microbes use energy to convert non-protein nitrogen to microbial protein. In the grazing cow however, the rumen microbes use non-protein nitrogen with only 80% efficiency (compared to true protein), which reduces the overall value of crude protein.

Urea is a source of non-protein nitrogen. However, to avoid toxicity, no more than 1 per cent dry matter of a cow’s diet should consist of urea.

Rumen degradable protein

Rumen degradable protein (RDP) is any protein in the diet that is broken down (digested) and used by the microbes in the rumen. If enough energy (particularly carbohydrate) is available in the rumen, some of the digested RDP will be used to produce microbial protein.

Undegradable dietary protein

Undegradable dietary protein (UDP) is any protein in the diet that is not digested in the rumen. It is digested ‘as eaten’, further along the gut. That’s why UDP is sometimes called ‘bypass protein’.

The proportion of the protein in the diet which bypasses rumen digestion (that is, becomes UDP) varies, depending on how well the protein is protected from the microbes. Feeds can be treated with heat or chemicals to ‘protect’ the protein.
However, it is possible to ‘over-protect’ protein. It then moves through the entire gut and out the other end without being digested.

The UDP of feeds also depends on how much is eaten in total, and how quickly the feed flows through the rumen. Greater intake and faster flow-through mean more protein becomes UDP because it simply ‘escapes’ through the rumen before microbial breakdown occurs.

### 3.3.2 Measuring rumen degradable protein and undegradable protein

You may want to know how much of the crude protein in the feed is RDP and how much is UDP. This analysis is called protein degradability.

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 and 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.

Nevertheless, a system describing the degradability of protein has been developed to help farmers assess the UDP supply in feeds. This classification is shown in Table 3.3.

### Table 3.3: Categories used to assess ability of feeds to supply undegradable dietary protein (UDP).

<table>
<thead>
<tr>
<th>Category</th>
<th>Undegradable Dietary Protein</th>
<th>Rumen Degradable Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>more than 69%</td>
<td>less than 31%</td>
</tr>
<tr>
<td>Good</td>
<td>69-50%</td>
<td>31-50%</td>
</tr>
<tr>
<td>Moderate</td>
<td>49-30%</td>
<td>51-70%</td>
</tr>
<tr>
<td>Poor</td>
<td>29-10%</td>
<td>71-90%</td>
</tr>
</tbody>
</table>

### 3.4 Fibre

Fibre is the cell wall, or structural material, in a plant and is made of hemicellulose, cellulose, and lignin. Some of the fibre is digestible, some is not.
3.4.1 Types of fibre

There are three methods of describing the fibre in a cow's diet.

**Neutral detergent fibre**

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. A high NDF might mean lower intake because of the bulk. Conversely, lower NDF values lead to higher intakes.

**Acid detergent fibre**

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).

**Crude fibre**

Crude fibre (CF), although sometimes used to indicate fibre content, is now considered an unacceptable measure. It does not include all of the constituents that make up the fibre component of a feed.

3.4.2 Measuring fibre

**Figure 3.4** shows the different approaches to measuring fibre.

Sometimes the fibre in the diet is expressed as kilograms of dry matter; but more often, fibre is expressed as a percentage of the dry matter. For example, if a feed has a neutral detergent fibre measurement of 25 per cent NDF, one-quarter of the dry matter weight is fibre.
3.5 Vitamins and minerals

3.5.1 Vitamins

The vitamin needs of most ruminants are met under normal conditions by natural feeds, microbial activity in the rumen, and tissue synthesis.

Vitamins A, D, and E are usually present in adequate amounts in high-quality forage. Members of the B-vitamin group and vitamins K and C are synthesised in the tissues and rumen.

Vitamins are either water soluble or fat soluble. The water-soluble vitamins of importance to cows are the B group of vitamins and vitamin C. The important fat-soluble vitamins are A, D, E, and K.

Vitamins are normally expressed in international units (IU).

Vitamin deficiencies are rare in normal grazing situations.

3.5.2 Minerals

About 21 minerals are essential for animal health and growth. However, many of these can become toxic if the animal eats too much of them.
Chapter 3. What’s in Feeds?

Mineral deficiencies are less likely if pasture is the major part of the diet.

High-producing herds fed diets high in cereal grain or maize silage may require added minerals.

The mineral content of feed is expressed in units of weight: grams (g) or milligrams (mg).

3.6 Essential nutrients and sources summary

Essential nutrients, their sources in feed and the units by which they are measured are summarised in Table 3.4.

Table 3.4: Sources and units of measurement of nutrients essential in the diet of dairy cows.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Source in feed</th>
<th>Unit of measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>Carbohydrates</td>
<td>Megajoules of metabolisable energy per kg of Dry matter (MJ ME/kg DM)</td>
</tr>
<tr>
<td></td>
<td>Fats and oils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Protein</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Rumen degradable protein (RDP)</td>
<td>Crude protein percentage (CP %)</td>
</tr>
<tr>
<td></td>
<td>Undegradable protein (UDP)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-protein nitrogen (NPN)</td>
<td></td>
</tr>
<tr>
<td>Fibre</td>
<td>Structural carbohydrates</td>
<td>% Neutral detergent fibre (% NDF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Acid detergent fibre (% ADF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Crude fibre (% CF)</td>
</tr>
<tr>
<td>Vitamins</td>
<td>Present in feeds</td>
<td>International units (IU)</td>
</tr>
<tr>
<td></td>
<td>Some synthesised by microbes in the rumen</td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td>Present in feeds</td>
<td>Grams (g) or milligrams (mg)</td>
</tr>
</tbody>
</table>
4. **How the Rumen Works**

4.1 *The digestive system*

Three steps are involved in cows obtaining nutrients from their diet:

*Ingestion*: taking food into the body;

*Digestion*: food is mechanically and chemically broken down; and

*Absorption*: nutrients pass from the digestive system into the cow's blood stream.

The digestive system of dairy cows is well adapted to a diet of plant material. As ruminants, cows have one true stomach (the abomasum) and three other compartments (the rumen, the reticulum and the omasum) which each have specific roles in the breakdown of the feed consumed. These are shown in **Figure 4.1**.

![Digestive system of the dairy cow.](image)

**Figure 4.1**: Digestive system of the dairy cow.
Chapter 4. How the Rumen Works

4.1.1 The rumen and the reticulum

Once food has been ingested, it is briefly chewed and mixed with saliva, swallowed and passed down the oesophagus into the rumen. The rumen is adapted for the digestion of fibre. It is the largest compartment of the adult ruminant stomach.

The rumen is sometimes described as a 'fermentation vat'. Its internal surface is covered with tiny projections called papillae; these increase the surface area of the rumen and allow better absorption of digested nutrients.

The reticulum is separated from the rumen by a ridge of tissue. Its lining has a raised honeycomb-like pattern, also covered with small papillae.

The rumen and reticulum together have a capacity of 50–120 litres of food and fluid. The temperature inside the rumen remains stable at around 39°C (38–42°C) which is suitable for the growth of a range of micro-organisms (microbes).

The microbes break down feed through the process of fermentation. Under normal conditions, the pH of the contents of the rumen and reticulum is maintained in the range of 6–7. (It may be lower in grain-fed cows.)

The stable pH range is maintained by continual removal, via the rumen wall, of acidic end products of microbial fermentation, and by the addition of bicarbonate from the saliva.

Saliva

Saliva has several roles: it makes chewing and swallowing easier, but primarily it contains sodium (Na) and potassium (K) salts that act as buffering agents against acidity.

A cow can produce 150 L or more of saliva daily. The volume of saliva secreted depends on the time spent eating and ruminating.

Chewing and rumination

Before food reaches the rumen its breakdown has already begun by the mechanical action of chewing.
Chapter 4. How the Rumen Works

Chemical breakdown is initiated by enzymes produced by the microbes in the rumen.

The walls of the rumen and reticulum move continuously, churning and mixing the ingested feed with the rumen fluid (or 'digestive chemicals') and microbes. The contractions of the rumen and reticulum help the flow of finer food particles into the next chamber, the omasum.

Rumination, or chewing the cud, is the process whereby newly eaten feed is returned to the mouth for further chewing. This extra chewing breaks the feed down into smaller pieces, thereby increasing its surface area. The smaller surface area in turn makes the feed more accessible to the chemicals which break it down. As a result, the rate of microbial digestion in the rumen is increased.

The time spent ruminating (chewing the cud) depends on the fibre content of the feed. The more fibre in the feed, the longer the ruminating time, therefore the less feed that can be eaten overall, and the less milk produced.

Some nutrients are absorbed across the rumen wall. Absorption involves the movement of individual feed components through the wall of the digestive tract into the bloodstream by which they are transported to the liver.

There is a constant flow of digesta through the digestive tract. Because food larger than 1 mm cannot leave the rumen until its length is reduced, the rumen is probably the major regulator of feed intake.

**Passage of food through the rumen**

The passing of material through the rumen affects the extent of digestion. General rate of passage depends on density, particle size, ease of digestion and level of feeding. Some foods pass through the digestive system fairly quickly, but very indigestible food may be excreted over a long period.

**4.1.2 Microbes of the rumen and reticulum**

The micro-organisms or microbes in the rumen include bacteria, protozoa and fungi. These microbes feed on forages ingested by the cow, and, by fermentation, produce end products that are utilised by the cow as well as by the microbes themselves for their own reproduction and cell growth.
Chapter 4. How the Rumen Works

Bacteria and protozoa are the most important microbes. Billions of bacteria and protozoa are found in the rumen. They digest about 70–80 per cent of the digestible dry matter in the rumen.

Different species of bacteria and protozoa perform different functions. Some digest starch and sugar while others digest cellulose. The numbers and proportions of each type of microbe depend on the individual animal’s diet.

Maintaining a healthy mixture of different microbes is essential for keeping the rumen functioning efficiently.

The major end products of microbial fermentation are:

*Volatile fatty acids (VFAs)*, mainly acetate, propionate and butyrate. These are products of fermentation and are the cow’s main energy source.

*Ammonia*, which can be used to manufacture microbial protein. Bacteria are 60 per cent protein, making them the major source of protein for the cow as they leave the rumen and are digested in the abomasum and small intestine.

*Gases*, mainly methane and carbon dioxide, are a source of wasted energy as they are belched out regularly.

Dietary upsets, such as feeding too much grain too quickly, can cause a rapid change in the microbial population. This changes fermentation patterns and interferes with fibre digestion. Adjusting the level of grain fed should therefore be done gradually so that the populations of rumen microbes can adjust accordingly.

4.1.3 Rate of digestion

The speed of digestion of feeds depends on the quality and composition of the feed. It is affected by the number and type of microbes, the pH in the rumen, the nutrients limiting the growth of the microbes and the removal of microbes from the rumen.

Energy and protein are the major nutrients which limit microbial growth and therefore rumen fermentation.

The microbial population needs energy and protein for growth and multiplication. If either of these nutrients is in
short supply, microbial growth is retarded, and so is the rate of digestion (the digestibility) of feed.

4.1.4 Omasum

The omasum lies between the reticulum and abomasum. The material entering the omasum is made up of 90–95 per cent water. The primary function of the omasum is to remove some of this water and to further grind and break down feed.

Large plate-like folds, known as laminae, extend from the walls of the omasum. These folds are attached in the same way as pages are bound to the spine of a book. The laminae are covered in papillae which direct the flow of food particles towards the next chamber, the abomasum.

4.1.5 Abomasum

The abomasum connects the omasum to the small intestine.

Acid digestion, rather than microbial fermentation, takes place in the abomasum, much the same as in the human stomach.

The lining of the abomasum is folded into ridges which produce gastric juices containing hydrochloric acid and enzymes (pepsins). The pH of these gastric juices varies from 1 to 1.3 making the abomasum very acid, with a pH of about 2.

The acidity in the abomasum kills the rumen microbes.

The pepsins carry out the initial digestion of microbial and dietary protein in the abomasum.

4.1.6 Small intestine

From the abomasum the digested food moves to the small intestine. There, enzymes continue the digestion of feeds and microbes. Most nutrient absorption occurs in the small intestine.
4.1.7 Large intestine

The large intestine, mainly the caecum and colon, is the site of secondary fermentation, particularly of fibre. Ten to 15 per cent of the energy used by the cow is absorbed from the large intestine. Absorption of water, minerals and ammonia also occurs here.

The components of feed not digested in the large intestine are passed through the rectum and anus and expelled as faeces.

4.2 Carbohydrate digestion in the rumen

When food is eaten by the cow, the nutrients are initially in the form of carbohydrates, proteins and fats (or lipids). These are digested to products which can be used directly by the cow or by the microbes in the rumen.

Plant tissue dry matter is about 75 per cent carbohydrate. Microbial fermentation breaks carbohydrates down into simple sugars. The microbes use these sugars as an energy source for their own growth and make end products which are used by the cow.

The end products of microbial fermentation of carbohydrates include:

- volatile fatty acids (mainly acetate, propionate and butyrate)
- gases (carbon dioxide and methane).

All carbohydrates are fermented by rumen microbes, but the soluble and storage forms are fermented more quickly than the structural forms. Sugars and starches are broken down easily and quickly. By comparison, cell-wall material is digested slowly.

As plants mature their cell walls become lignified. The lignin reduces the availability and utilisation of structural carbohydrates. In other words, as plants mature their digestibility declines because the components of their cell walls become less accessible and harder to digest.

Soluble carbohydrates are digested 100 times faster by the microbes in the rumen than are storage carbohydrates, and storage carbohydrates are digested about five times faster than the structural carbohydrates.
Figure 4.2 shows the relationship between digestibility and speed of digestion for some common feeds.

![Graph showing relationship between digestibility and rate of digestion for various feeds.](Source: Ørskov 1987)

4.2.1 Structural carbohydrates

Bacteria which digest structural carbohydrates (cellulose and hemicellulose) produce a large proportion of acetic acid, which is important in the production of milkfat. 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 be completely eliminated or their growth rate slowed down. Reduction or elimination of these bacteria not only reduces the digestibility of the feed, it may also reduce the cow’s intake of feed.

Once structural carbohydrates have passed through the rumen, there is little likelihood that they will be broken down further.
4.2.2 Storage carbohydrates

The bacteria that digest starchy feeds (e.g. cereal grains or potatoes) are quite different from the cellulose-digesting bacteria. They are insensitive to acidity and produce mainly propionic acid. Starches are rapidly fermented, and the lactic and propionic acid they produce causes acidity to increase.

The acidity caused by excess starch-digesting bacteria can suppress the bacteria which digest cellulose and so reduce the milkfat test.

4.2.3 Soluble sugars

The bacteria that ferment feeds high in soluble sugars (e.g. molasses, beets, turnips and good quality grass) are similar to those that ferment starch.

Sugary feeds generally cause fewer problems with increased acidity in the rumen than starchy feeds (see below). However, care still needs to be taken when introducing sugary feeds to the cow’s diet.

4.2.4 The products of carbohydrate digestion

Volatile fatty acids

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

- They are the major source of energy for the ruminant (about 70 per cent of the total)
- The proportions in which they are produced determine fat and protein content of milk.

The three major volatile fatty acids produced are acetate (or acetic acid), propionate (or propionic acid) and butyrate (or butyric acid). The ratio of the various VFAs produced depends on the type of feed being digested.

Volatile fatty acids are absorbed through the walls of the rumen then transported in the bloodstream to the liver. In the liver they are converted to other sources of energy. From the liver, the energy produced is used to perform various functions (i.e. milk production, maintenance of body systems, pregnancy and growth). This is shown in Figure 4.3.
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Non-fibrous Carbohydrates  
(cell contents)

Fibrous Carbohydrates  
(cell wall)

**DIET**

- Soluble Sugars
- Storage Starch
- Structural Pectin

**RUMEN**

- Absorbed across the rumen wall and carried by the blood stream to the liver.
- Used as an energy source for:
  - Maintenance
  - Activity
  - Milk production
  - Body condition
  - Pregnancy
  - Growth

**Figure 4.3:** Digestion of carbohydrates, and production and absorption of volatile fatty acids in the dairy cow.

**Acetate**

Acetate is an end product from the fermentation of fibre. Highly fibrous, low energy feeds such as pasture hay lead to microbial populations which produce high ratios of acetate to propionate.

*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.

**Propionate**

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

*Most of the energy needed for liveweight gain and for the mammary system to produce lactose, is obtained from propionate.*

Feeds high in rapidly fermentable carbohydrates such as cereal grains lead to populations of bacteria which produce relatively more propionate and butyrate than acetate.
Propionate is considered a more efficient energy source because fermentations which favour the production of propionate produce 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.

Butyrate

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

Ketone bodies are also produced from the mobilisation of body fat.

If a cow is underfed in early lactation and loses body condition to compensate for a lack of dietary energy, the ketone bodies are utilised as an alternative energy source.

Gas

Carbon dioxide and methane are produced during the fermentation of carbohydrates. They are either removed through the rumen wall or lost by eructation (belching).

Some carbon dioxide is used by the intestinal microbes and by the cow to maintain bicarbonate levels in saliva.

Methane cannot be used by the cow’s body systems as a source of energy.

4.3 Digestion of protein

Protein, when digested, is broken down into peptides which are short chains of amino acids. Further digestion of peptides yields individual amino acids and eventually ammonia.

The protein used by the cow may be from the feed she eats or from the microbes washed from the rumen. The amount of each depends on the extent to which dietary protein is degraded in the rumen and on the growth and outflow of
microbes from the rumen. This is shown diagrammatically in Figure 4.4.

![Diagram of protein breakdown and partitioning](image)

**Figure 4.4:** Breakdown and partitioning of dietary and microbial protein sources in the dairy cow.

### 4.3.1 Microbial protein

Rumen microbes are 60 per cent protein. They are the major source of protein in the cow’s diet.

Microbes of the rumen break down rumen degradable protein (RDP) to amino acids then ammonia. Ammonia is a major source of nitrogen for microbial growth. The microbes also convert non-protein nitrogen to ammonia.

Microbes are continually ‘flushed’ from the rumen, through the omasum to the next chamber, the abomasum, where they die and are digested by the cow.

The amino acids produced when microbial protein is digested are then absorbed through the small intestine.
The amount of microbial protein flowing to the intestines depends on the availability of energy and ammonia in the cow’s diet.

*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 and some is recycled back into the rumen as non-protein nitrogen in saliva.

*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. Generally, though, pasture-based diets are relatively high in protein.

### 4.3.2 Dietary protein

The dietary protein that is directly available to the cow is undegradable protein (UDP) and any rumen degradable protein (RDP) which has escaped microbial digestion. This protein is digested in the abomasum and small intestine.

UDP and 'escape RDP' provide a greater diversity of amino acids than does protein broken down in the rumen, which is restricted to those proteins, and their component amino acids, found in microbes.

### 4.4 Digestion of fats

Fats are a source of energy for the cow. Fats are either partially degraded in the rumen or assume a bypass or protected form. When microbial fermentation of fats occurs in the rumen, some vitamins required by the cow are also produced.

Fats are present in most of the more common dairy feeds in relatively small amounts (2–3 per cent of pasture dry matter can be fat).
No more than 5 per cent of total diet dry matter (or about 500 g/day) should consist of fats.

Beyond this, level fat will coat the dietary fibre in the digestive tract. This interferes with fibre digestion and decreases the palatability of the diet.

Protected fats, which escape microbial digestion in the rumen, can be used to overcome the digestive upsets caused by high levels of rumen-degradable fat. The protected fats are readily digested and absorbed across the wall of the small intestine.

Interest in feeding fats (e.g. Prime, Megalac etc.) to lactating dairy cows is growing. However, they are only relevant to higher producing herds (30 litres or more).

Fats such as those from oilseeds (e.g. whole cottonseed) are useful to such herds because they increase the energy density of the diet, particularly in early lactation, thus helping to reduce live weight loss.
Chapter 4. How the Rumen Works
5. Nutrient Requirements of Dairy Cows

5.1 Water

In temperatures of 15–20°C, a lactating dairy cow needs 30–40 litres of water each day for maintenance, plus an extra 4–5 litres for each litre of milk produced.

Water requirements increase as air temperatures increase. Lactating cows will drink 150 to 200 litres of water per day in the summer months.

Other factors influencing water intake include diet composition (dry matter intake), humidity, wind speed, water quality (sodium and sulphate levels), temperature and pH.

5.2 Energy

Cows need energy for maintenance, activity, pregnancy, milk production and for gaining body condition.

5.2.1 Maintenance

Energy is used for maintaining the cow’s metabolism. This includes breathing and maintaining body temperature. Physical activity such as walking and eating adds to the maintenance requirement, as does environmental temperature and physiological state (i.e. pregnancy and lactation).

Table 5.1 shows the energy needed for maintenance at various liveweights. These values include a 5 per cent safety margin.

5.2.2 Energy needed for activity

An allowance for grazing activity has been factored into the maintenance requirements in Table 5.1. In flat terrain, 1 MJ ME per kilometre should be added to provide the energy needed to walk to and from the dairy. In undulating terrain, 5 MJ ME are required per kilometre.
### Table 5.1: Energy requirements for maintenance.

<table>
<thead>
<tr>
<th>Liveweight (kg)</th>
<th>Energy requirement (MJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>17</td>
</tr>
<tr>
<td>150</td>
<td>22</td>
</tr>
<tr>
<td>200</td>
<td>27</td>
</tr>
<tr>
<td>250</td>
<td>31</td>
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<td>300</td>
<td>36</td>
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<td>350</td>
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<td>550</td>
<td>59</td>
</tr>
<tr>
<td>600</td>
<td>63</td>
</tr>
<tr>
<td>700</td>
<td>72</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)

### 5.2.3 Energy needed for pregnancy

A pregnant cow needs extra energy for the maintenance and development of the calf inside her. From conception through the first five months of pregnancy, the additional energy required is approximately 1 MJ/day for each month of pregnancy.

Energy requirements for pregnancy only become significant in the last four months. **Table 5.2** shows the average daily energy requirements during these last months.

### Table 5.2: Average daily energy requirements in the last four months of pregnancy.

<table>
<thead>
<tr>
<th>Month of pregnancy</th>
<th>Additional energy required (MJ/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sixth</td>
<td>8</td>
</tr>
<tr>
<td>Seventh</td>
<td>10</td>
</tr>
<tr>
<td>Eighth</td>
<td>15</td>
</tr>
<tr>
<td>Ninth</td>
<td>20</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)

### 5.2.4 Energy needed for milk production

Energy is usually the most important feed component needed to produce milk. The energy needed depends on the composition of the milk (i.e., fat and protein content).
Table 5.3 shows the energy needed to produce a litre of milk with a range of fat and protein tests. High-testing milk might need 7.1 MJ for each litre, whereas low-testing milk might need only 4.5 MJ for each litre.

Table 5.3: Energy needed per litre of milk of varying composition.

<table>
<thead>
<tr>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>2.6</th>
<th>2.8</th>
<th>3.0</th>
<th>3.2</th>
<th>3.4</th>
<th>3.6</th>
<th>3.8</th>
<th>4.0</th>
<th>4.2</th>
<th>4.4</th>
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</thead>
<tbody>
<tr>
<td>3.0</td>
<td>4.5</td>
<td>4.5</td>
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<td>6.3</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>5.2</td>
<td>5.9</td>
<td>6.0</td>
<td>6.0</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
<td>6.4</td>
<td>6.4</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>5.4</td>
<td>6.0</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
<td>6.4</td>
<td>6.5</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>5.6</td>
<td>6.2</td>
<td>6.2</td>
<td>6.3</td>
<td>6.4</td>
<td>6.5</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.7</td>
<td>6.7</td>
<td>6.8</td>
</tr>
<tr>
<td>5.8</td>
<td>6.3</td>
<td>6.4</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>6.7</td>
<td>6.7</td>
<td>6.8</td>
<td>6.9</td>
<td>6.9</td>
<td>6.9</td>
</tr>
<tr>
<td>6.0</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.7</td>
<td>6.8</td>
<td>6.9</td>
<td>6.9</td>
<td>7.0</td>
<td>7.0</td>
<td>7.1</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)

From the section dealing with energy and activity and Tables 5.1–5.3, you can calculate that a 500 kg cow:

- walking 1 km per day on flat terrain,
- producing 10 litres of milk (4.0 per cent fat, 3.6 per cent protein),
- in the sixth month of pregnancy, requires:

\[ 54 + 1 + 8 = 63 \text{ MJ/d} \]

(maintenance, activity and pregnancy).

PLUS

\[ 10 \times 5.5 = 55 \text{ MJ/d} \] (milk production).

The cow’s energy requirement is therefore 63 + 55 = 118 MJ/d.
5.2.5 Energy needed for body condition

When an adult cow puts on weight, she puts it on mostly as fat. You can notice some of this fat on the backbone, ribs, hip bones and pin bones and around the head of the tail. This extra fat is called body condition and can be scored by visual appraisal. A very skinny cow might score 3 and a fat cow might score 6.

An alternative to scoring the extra condition on a cow would be to weigh her. Weighing a cow to determine if she has put on condition is more accurate, because condition score is affected by the cow’s body shape. More fat is needed to show one extra body condition score on a large-framed cow than on a small-framed cow. Charts are available to help you assess condition score.

Table 5.4 shows how much different condition scores weigh. Generally, the amount of weight gain required to increase the cow’s condition by one condition score is about 8 per cent of the cow’s current liveweight.

<table>
<thead>
<tr>
<th>Cow’s approximate liveweight (kg)</th>
<th>Additional weight to increase by one condition score (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>550 (Friesian)</td>
<td>44</td>
</tr>
<tr>
<td>475 (Friesian X Jersey)</td>
<td>38</td>
</tr>
<tr>
<td>400 (Jersey)</td>
<td>32</td>
</tr>
</tbody>
</table>

Energy is stored as fat when a cow gains body condition. Conversely, energy is released when body condition is lost, or taken off.

Table 5.5 shows how much energy is needed for condition gain and how much is released when condition is lost. Notice that gaining a kilogram in the dry period takes more energy than gaining it in late lactation. Although it is worthwhile for cows to gain condition when dry, it is more efficient to feed for body condition in late lactation.
Table 5.5: The energy a kilogram of body weight or condition needs or releases.

<table>
<thead>
<tr>
<th>Change in body condition</th>
<th>MJ needed to gain 1 kg of weight</th>
<th>MJ available from 1 kg of weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late lactation gain</td>
<td>44</td>
<td>-</td>
</tr>
<tr>
<td>Dry period gain</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Weight loss</td>
<td>-</td>
<td>28</td>
</tr>
</tbody>
</table>

**EXAMPLE 5.1:** A cow is losing 0.5 kg of liveweight per day (normal in the first months of lactation).

This means an additional 14 MJ is available for milk production each day (see Table 5.5). The 14 MJ released each day can produce about 2–3 litres of milk each day depending on milk composition (see Table 5.3).

**EXAMPLE 5.2:** A 550-kg Friesian cow in late lactation, is putting on half a condition score.

This means 22 kg of liveweight needs to be gained (see Table 5.4). This requires an additional 968 MJ (44 MJ x 22 kg) over the period of weight gain (see Table 5.5).

The cow needs this energy in addition to the energy required each day for maintenance, activity, pregnancy and milk production.

**EXAMPLE 5.3:** A 550 kg dry Friesian cow, putting on one condition score in 6 weeks (42 days):

This means 44 kg of liveweight needs to be gained (see Table 5.4). The weight gain will require an additional 2420 MJ (55 MJ x 44 kg) (see Table 5.5). Spread over 42 days, this is 58 MJ each day just for condition gain.

As well, the cow probably needs 20 MJ per day for her calf (see Table 4.3) and 59 MJ for maintenance (Table 5.1).

These add up to a grand total of 137 MJ per day.

Let us assume the cow’s daily intake capacity is 12 kg dry matter (DM). Therefore, the feed energy content would have to be at least 12.7 MJ/kg DM (152 MJ/d ÷ 12 kg/d). No wonder you cannot put condition on a dry cow with hay at, say, 8 MJ/kg DM.
5.2.6 Effect of climatic stress on energy requirements

Cold stress is unlikely to directly influence the energy requirements of milking cows in Victoria. However, cold wet conditions can influence grazing behaviour which could reduce intakes of grazed pasture.

When animals are heat stressed to the point that they are panting, their energy requirements for maintenance can be increased by up to 10 per cent. It is possible that this will happen for periods of several hours in mid-afternoon on very hot summer or autumn days. When considering the full 24 hours in each day, the heat stress is unlikely to increase the maintenance requirements of the animal.

**EXERCISE 5.1:** Seven cows of different sizes, are at different stages of pregnancy and producing different amounts of milk. Lactating animals are walking 2 km per day to the dairy on flat terrain.

*Calculate the daily energy requirements of these cows.*

<table>
<thead>
<tr>
<th>COW DETAILS</th>
<th>Description</th>
<th>Cow 1</th>
<th>Cow 2</th>
<th>Cow 3</th>
<th>Cow 4</th>
<th>Cow 5</th>
<th>Cow 6</th>
<th>Cow 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (kg LWt)</td>
<td></td>
<td>500</td>
<td>550</td>
<td>450</td>
<td>600</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td></td>
<td>7th</td>
<td>Empty</td>
<td>6th</td>
<td>9th</td>
<td>7th</td>
<td>7th</td>
<td>Empty</td>
</tr>
<tr>
<td>Daily milk prod’n (L)</td>
<td></td>
<td>13</td>
<td>27</td>
<td>18</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Fat test (%)</td>
<td></td>
<td>4.4</td>
<td>4</td>
<td>5.2</td>
<td>-</td>
<td>4.8</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Protein test (%)</td>
<td></td>
<td>3.4</td>
<td>3.2</td>
<td>3.6</td>
<td>-</td>
<td>3.6</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>LWt gain / loss (kg/d)</td>
<td></td>
<td>+1.5</td>
<td>-1</td>
<td>0</td>
<td>+2</td>
<td>+1.5</td>
<td>0</td>
<td>+1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENERGY REQUIREMENTS (MJ ME)</th>
<th>Category</th>
<th>Cow 1</th>
<th>Cow 2</th>
<th>Cow 3</th>
<th>Cow 4</th>
<th>Cow 5</th>
<th>Cow 6</th>
<th>Cow 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pregnancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk production</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13x6</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>Weight gain or loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5x44</td>
<td></td>
<td>66</td>
</tr>
<tr>
<td>Total energy requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>210</td>
</tr>
</tbody>
</table>
5.3 Protein

The amount of protein a cow needs depends on her size, growth, milk production, and stage of pregnancy. However, milk production is the major influence on protein needs. Table 5.6 shows crude protein needs at different levels of milk production.

As discussed earlier, protein is measured as crude protein, rumen degradable protein (RDP) or undegradable protein (UDP).

Table 5.6: Crude protein needs of a cow at different production levels.

<table>
<thead>
<tr>
<th>Milk production</th>
<th>Crude protein requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early lactation</td>
<td>16 - 18%</td>
</tr>
<tr>
<td>Mid-lactation</td>
<td>14 - 16%</td>
</tr>
<tr>
<td>Late lactation</td>
<td>12 - 14%</td>
</tr>
<tr>
<td>Dry</td>
<td>10 - 12%</td>
</tr>
</tbody>
</table>

When calculating the protein requirements of the herd, crude protein, RDP or UDP figures can be used. Remember though that requirements for RDP and UDP are only ‘guesstimates’.

To work out how much RDP and UDP is required, the protein requirements of the rumen microbes and of the cow need to be considered. The microbial protein made available (after it is flushed from the rumen) also needs to be calculated. Any shortfall in protein can then be made up by other protein sources (i.e. UDP). However, 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 used by the cow. As a result, RDP and UDP requirements can only be calculated estimates.
5.3.1 How milk production affects requirements for rumen degradable protein and undegradable dietary protein

Above a certain level of milk production, some protein in the diet must be UDP. There is a limit to the rumen’s capacity to use RDP to produce microbial protein which can then be flushed on to the small intestine for digestion.

Microbial protein coming out of the rumen can sustain milk production to 12 litres. In other words, when milk production is 12 litres or less, all the protein in the diet can be RDP (i.e. protein that the microbes can use).

However, for milk production over 12 litres, at least some protein in the diet must be UDP. The need for UDP increases as milk production rises. Results from pastures analysed in Victoria reveal that from 20 to 30 per cent of the total protein content is UDP or bypass protein.

It is unlikely that cows grazing good quality pasture and producing less than 30 litres per day will need to be supplemented with additional UDP.

5.4 Fibre

Cows need a certain amount of fibre in their diet to ensure that the rumen functions properly and to maintain the fat test.

Table 5.7 shows the levels of fibre cows need in their diet. It should be stressed that the fibre requirements listed are the absolute minimum values. Acceptable levels of neutral detergent fibre (NDF) in the diet are in the range 30–35 per cent of dry matter (DM).

Table 5.7: The absolute minimum percentage of fibre needed in a cow’s diet for healthy rumen function (using three different measures of fibre).

<table>
<thead>
<tr>
<th>Fibre measurement</th>
<th>Minimum amount of fibre in the diet (per cent of total dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral detergent fibre</td>
<td>30%</td>
</tr>
<tr>
<td>Acid detergent fibre</td>
<td>19%</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>17%</td>
</tr>
</tbody>
</table>
Chapter 5. Nutrient Requirements of Dairy Cows

Low-fibre, high-starch diets cause the rumen to become acid. Grain poisoning (acidosis) may occur. Adding buffers such as sodium bicarbonate to the diet reduces acidity and hence reduces this effect.

Buffers are usually recommended when grain feeding exceeds 4–5 kg of grain/cow/day.

Buffers are not a substitute for fibre. Long-term feeding of low-fibre diets should be avoided.

5.5 Vitamins and minerals

Some farmers spend a great deal of money on vitamin and mineral supplements for their cows. Production benefits only occur when the supplements correct a deficiency. So before purchasing the vitamin and mineral supplements, find out whether a deficiency actually exists. In some instances, supplementing animals that don’t have a deficiency may lead to poisoning and even death.

5.5.1 Vitamins

To the best of current knowledge, an oversupply of water-soluble vitamins will not harm cows. Any excess is simply excreted in the urine.

However, fat-soluble vitamins (the important ones being vitamins A, D, E and K) are stored in the cow’s body, and an oversupply of vitamin A or D can cause poisoning or death.

Vitamin A

Vitamin A is also called retinol. It is formed from betacarotene in the diet. It is required by the retina for good eyesight and is needed for tissue and bone formation, growth, milk production and reproduction. Vitamin A maintains healthy epithelium (e.g. the lining of the teat canal), so deficiencies may increase the incidence of mastitis infections.

100,000 IU of vitamin A are needed per day per cow.

Any surplus is stored in the liver for up to four months.

Vitamin A deficiency is uncommon in grazing cattle but may occur on diets high in cereal grains or cereal straw or
if cattle are grazed on dry pasture for more than six months.

**Vitamin D**

Vitamin D is formed in the skin when stimulated by sunlight. Vitamin D is required for calcium and phosphorus metabolism in the body. It stimulates calcium absorption in the small intestine. It also mobilises calcium stores from the bones. It can therefore be used to alleviate milk fever. Cows need 50,000 IU of vitamin D per day.

Vitamin D deficiencies are very rare in grazing stock. Vitamin D toxicity (perhaps due to excessive treatment for milk fever) causes calcification of soft tissues, especially the aorta.

**Vitamin E**

Vitamin E, selenium and vitamin A all help the cow's immune system to function properly. The immune system fights infections and helps cows clean up after calving. Cows need 1,000 IU of vitamin E per day. Higher amounts may be required around calving time.

Vitamin E deficiencies can lead to poor reproductive performance. Retained membranes, metritis, cystic ovaries, and low conception rates have all been linked to vitamin E deficiency.

Vitamin E deficiency also causes muscle degeneration, stiffness, and unco-ordinated movement, and may cause early embryonic loss.

### 5.5.2 Minerals

**Essential macrominerals**

Macrominerals are those required in quantities of grams per kilogram of dry matter (g/kg DM) or per cent DM. They include calcium, phosphorus, magnesium, potassium, sodium, sulphur and chlorine.

**Essential microminerals**

Microminerals are those required in quantities of milligrams per kilogram of dry matter (mg/kg DM), or parts per million (ppm). They include cobalt, copper, iron, iodine, manganese, zinc, selenium and molybdenum.
It is very difficult to estimate the mineral requirements of cows because the requirement varies according to the absorption efficiency of the mineral, the production stage and age of the animal, the environment, and the interaction with other minerals.

Mineral deficiencies are less likely if pasture is the major part of the diet. High-producing herds fed diets high in cereal grain or maize silage may need added minerals.

Additional information on minerals can be found in Appendix B.
A number of changes occur in a cow at the different stages of lactation. As well as changes in milk production, there are changes in feed intake and body condition, and also pregnancy.

A cow’s lactation may start at 15 litres of milk, rise to a peak of 25 litres at about seven weeks, and then gradually fall to 10 litres at the end of her lactation.

She will need more energy and protein as milk production increases, and less energy and protein when production declines. At all stages, she will need about the same amount of energy and protein each day for maintenance.

Obviously if a cow has no calf inside her, she does not need any energy or protein for pregnancy. Once she becomes pregnant she will need some extra energy and protein. However, the calf does not increase its size rapidly until the sixth month, at which time the nutrient requirement becomes significant.

The calf doubles its size in the ninth month, so at that stage a considerable amount of feed is needed to sustain its growth.

A cow usually takes off body condition for about twelve weeks after calving. The energy released is used to produce milk. It allows the cow to produce more milk and to achieve higher peak production than would be possible from her diet alone.

Of course, to do this she must have the body condition available to lose, and therefore must have put it on late in the previous lactation or during the dry period.

**6.1 From calving to peak lactation**

Milk yield at the peak of lactation sets up the potential milk production for the year; one extra litre per day at the peak may mean an extra 200 litres per cow for the full lactation. However, there are a number of obstacles to
feeding the herd well in early lactation to maximise the peak. The foremost of these is voluntary food intake.

At calving, appetite is about 75 per cent of maximum. This is because during the dry period the growing calf takes up space and the volume of the rumen is reduced. After calving, it takes time for the rumen to ‘stretch’. It is not until weeks 10–12 that appetite reaches its full potential.

In addition, spring pasture is very moist. It has a low dry matter content and so the rumen cannot hold enough pasture to meet the dry matter needs of the cow at this time. Peak milk production occurs around weeks 6–8 of lactation. So, when a cow should be gorging herself with energy, she is physically restricted in the amount she can eat. This is shown in Figure 6.1.

![Figure 6.1: Dry matter intake, milk yield and liveweight changes in a cow during the lactation cycle (cited by Lawson, 1994).](image)

Level of intake is primarily determined by stage of lactation, but it can be manipulated.

Table 6.1 shows that cows with restricted rumen capacity are more likely to be 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 – feed intake can be increased.
Table 6.1: Dry matter intake needed by cows producing at two levels of milk production and fed diets of different energy density.

<table>
<thead>
<tr>
<th>Milk Yield (litres/day)</th>
<th>Feed intake (kg DM/day)</th>
<th>ME requirement (MJ/kg DM)</th>
<th>10 MJ/kg DM</th>
<th>12 MJ/kg DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>168</td>
<td>16.8</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>220</td>
<td>22.0</td>
<td>18.3</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Stockdale, 1991)

A 30-litre cow would be struggling 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.

Cows in early lactation have a reduced capacity to eat. They will therefore produce a greater amount of milk from more energy dense feed 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. This is set out in Table 6.2.

Table 6.2: Effect of feeding levels after calving on milk production, liveweight gain and fertility in the first 20 weeks of lactation.

<table>
<thead>
<tr>
<th>Level of Feeding</th>
<th>Weeks 0 - 5</th>
<th>Weeks 5 - 10</th>
<th>Milk (litres)</th>
<th>Fat (kg)</th>
<th>Liveweight Gain (weeks 10 to 20) (kg/day)</th>
<th>Days to First Heat</th>
<th>Days to Conception</th>
</tr>
</thead>
<tbody>
<tr>
<td>High High</td>
<td>2998</td>
<td>133</td>
<td>0.36</td>
<td>38</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low High</td>
<td>2818</td>
<td>123</td>
<td>0.55</td>
<td>52</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Low</td>
<td>2668</td>
<td>113</td>
<td>0.45</td>
<td>38</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Low</td>
<td>2138</td>
<td>90</td>
<td>0.62</td>
<td>52</td>
<td>95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Grainger et al., 1982)

6.2 Peak lactation to peak intake

After peak lactation, the cow’s appetite gradually increases until she can consume all the nutrients required for
production from high quality feed (ie. there is no physical restriction on intake). During this time the cow tends to maintain weight.

6.3 Mid-lactation to late lactation

Although energy required for milk production is less demanding during this period because milk production is declining, energy is still important because of pregnancy and the need to build up body condition as an energy reserve for the next lactation.

Nutritional requirements generally exceed voluntary food intake until week 12, so body fat reserves are drawn upon to make up the nutrient deficit.

It is generally more profitable to improve the condition of the herd in late lactation rather than in the dry period. While lactating, cows use energy more efficiently for weight gain (75 per cent efficient compared to 59 per cent if dry). As well, the extra milk produced in response to the extra feed, gains higher autumn prices.

6.4 Dry period

Maintaining (or increasing) body condition during the dry period is the key to ensuring the cow has adequate body reserves for early lactation.

Ideally, cows should calve in a condition score of at least 5, and preferably 5 to 6. If cows calve with adequate body reserves on their back, one condition score can be lost in the first two months of lactation.

Each condition score lost (between score 3–6) in early lactation is equivalent to 220 litres of milk, 10 kg of fat and 6.5 kg of protein over the lactation.

Each additional condition score at calving reduces the time between calving and first heat by 5–6 days. The sooner the cow begins to cycle, the sooner she is likely to get into calf and the more compact the calving period next season.
If cows calve in poor condition, milk production suffers in early lactation because body reserves are not available to contribute energy.

As a result, more dietary energy is channelled towards weight gain. For this reason, high feeding levels in early lactation cannot make up for poor body condition at calving.

**EXERCISE 6.1:**

Information required for this exercise has been presented in Chapter 5 and Tables 5.1–5.7. The information is also grouped together in Appendix C.

On Worksheet 1 calculate the minimum requirements of the following cows:

a) A 500 kg cow in early lactation is producing 25 L/day of 4.2 per cent fat and 3.4 per cent protein milk. The dairy is 1 km away, the terrain is steep. At this stage of lactation she is losing 1 kg/day in bodyweight.

b) A 500 kg cow in mid-lactation is producing 15 L/day of milk with 4.4 per cent fat and 3.4 per cent protein. The dairy is 0.5 km away and the terrain is flat. Bodyweight is constant.
### Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 6.1a)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td><strong>A</strong> kg</td>
<td>For maintenance (Table 5.1)</td>
<td><strong>I</strong> MJ</td>
</tr>
<tr>
<td>Daily activity level</td>
<td><strong>B</strong></td>
<td>For activity</td>
<td><strong>J</strong> MJ</td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td><strong>B</strong> MJ/km</td>
<td>from B km</td>
<td></td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td><strong>D</strong> month</td>
<td>For pregnancy (Table 5.2)</td>
<td><strong>L</strong> MJ</td>
</tr>
<tr>
<td>Dry</td>
<td>10–12%</td>
<td>30%(NDF)</td>
<td></td>
</tr>
<tr>
<td>Daily milk production</td>
<td><strong>E</strong> litres</td>
<td>For milk production (Table 5.3)</td>
<td><strong>M</strong> MJ</td>
</tr>
<tr>
<td>Fat test</td>
<td><strong>F</strong> %</td>
<td>from E MJ/L</td>
<td></td>
</tr>
<tr>
<td>Protein test</td>
<td><strong>G</strong> %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td><strong>H</strong> kg/cow/day</td>
<td>For or from condition (Table 5.5)</td>
<td><strong>N</strong> MJ</td>
</tr>
<tr>
<td>gain + loss -</td>
<td><strong>H</strong></td>
<td>from H MJ/kg</td>
<td></td>
</tr>
</tbody>
</table>

**Total daily needs of this cow:**

- Energy: **I + J + L + M ± N** MJ
- Crude protein: **from above** %
- NDF fibre: **from above** %
### Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 6.1b)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>For maintenance (Table 5.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg</td>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily activity level</td>
<td>For activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td>X</td>
<td>J</td>
<td></td>
</tr>
<tr>
<td>MJ /km</td>
<td>from B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-lactation 14–16%</td>
<td>Early lactation 16–18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-lactation 14–16%</td>
<td>Late lactation 12–14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late lactation 12–14%</td>
<td>Dry 10–12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th month</td>
<td>For pregnancy (Table 5.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily milk production</td>
<td>For milk production (Table 5.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume litres</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat test</td>
<td>X</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>from E</td>
<td>MJ/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein test %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>For or from condition (Table 5.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg/cow/day</td>
<td>H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from H</td>
<td>MJ/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total daily needs of this cow:</td>
<td>EnergyMJ</td>
<td>Crude protein%</td>
<td>NDF fibre%</td>
</tr>
<tr>
<td>MJ I + J + L + M ± N</td>
<td></td>
<td>from above</td>
<td>from above</td>
</tr>
</tbody>
</table>

For a blank Worksheet, see Appendix F.
7. **Pasture Intake**

Dairy farmers in Victoria are fortunate to be able to provide most of their herds’ feed from grazed pasture rather than from costly supplements.

An understanding of the nutritional value of pasture is therefore paramount to good management of dairy cow nutrition. The nutritive value of pasture depends on how much pasture is eaten, its height and mass, its stage of maturity, the time of year and the dominant species in the sward. To get the best from pastures we should become skilled grazing managers.

The cow is the ‘harvester’ of our pastures, so we need to appreciate the cow’s grazing behaviour. In this chapter we look at the factors that affect how much pasture a cow will eat.

### 7.1 Factors affecting pasture quality

Quality of pasture can be roughly defined in physical terms.

Table 7.1 outlines the energy and protein contents of pastures referred to throughout this manual.

**Table 7.1: The energy and protein contents of pastures of differing quality.**

<table>
<thead>
<tr>
<th>Description of quality</th>
<th>Metabolisable Energy (MJ/kg DM)</th>
<th>Crude Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>more than 11</td>
<td>more than 20</td>
</tr>
<tr>
<td>Medium</td>
<td>9 to 11</td>
<td>14 to 20</td>
</tr>
<tr>
<td>Low</td>
<td>less than 9</td>
<td>less than 14</td>
</tr>
</tbody>
</table>

(Source: Stockdale, pers. comm.)

High quality pasture is leafy and contains little stemmy material. In other words, 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.

### 7.1.1 Pasture species

Table 7.2 lists the nutritive value of the major pasture species grown on Victorian dairy farms. The nutrient content will change with season, plant maturity and pasture height.

**Table 7.2: Nutritive value of individual pasture species.**

<table>
<thead>
<tr>
<th>Species</th>
<th>Energy (MJ/kg DM)</th>
<th>Crude Protein (%)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial ryegrass</td>
<td>10.5–11.0</td>
<td>17–18</td>
<td>30–50</td>
</tr>
<tr>
<td>White clover</td>
<td>11–11.5</td>
<td>22–25</td>
<td>25–35</td>
</tr>
<tr>
<td>Paspalum</td>
<td>7.5–9</td>
<td>8–14</td>
<td>40–70</td>
</tr>
</tbody>
</table>

While the differences in the energy levels of pasture species may seem small, remember that:

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 litres of milk per day.

### 7.1.2 Time of year and stage of maturity

The feed or nutritive value of pasture varies with the time of year and the stage of maturity of the dominant pasture species.


**Figures 7.1, 7.2, 7.3** show the typical variation in ‘well managed’ ryegrass/white clover pastures throughout the year in different dairying regions.

**Figure 7.1:** Seasonal variation in the energy and crude protein content of ryegrass (Rye) and white clover (WC) in Gippsland.
Chapter 7. Pasture Intake

Figure 7.2: Seasonal variation in the energy and crude protein content of ryegrass (Rye) and white clover (WC) in northern Victoria.
Figure 7.3: Seasonal variation in the energy and crude protein content of ryegrass (Rye) and white clover (WC) in western Victoria.

Generally, clover-dominant pastures have higher crude protein levels than do perennial ryegrass pastures. The reverse is true for energy content, except in summer and autumn.

The variation in nutritional value of pastures with season is 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 dominant species begin to mature, particularly ryegrass, the quality or nutritional value drops.

In irrigated pasture, paspalum tends to dominate and depress the overall nutritive value. Except in spring, when paspalum is still quite leafy (Table 7.3), pastures dominant in paspalum tend to have less energy and protein than ryegrass/white clover pastures (Table 7.2).

<table>
<thead>
<tr>
<th>Season</th>
<th>Energy (MJ/kg DM)</th>
<th>Crude Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>10.4</td>
<td>17.3</td>
</tr>
<tr>
<td>Summer</td>
<td>8.9</td>
<td>13.2</td>
</tr>
<tr>
<td>Autumn and June</td>
<td>9.1</td>
<td>14.4</td>
</tr>
</tbody>
</table>

7.1.3 Pasture selection

The figures in Table 7.3 are obtained from trials in which pasture was harvested by cutting. Unfortunately, harvested material is not always what a cow would choose to eat. In other words, cows graze selectively.

Researchers are defining how selective cows can be. In southern Australia researchers have begun to define a ‘selection allowance’ to align what is measured in harvest cuts with what a cow actually eats.

Dairy cows will select on average:
- 0.5 to 1 MJ more energy,
- 3–4 per cent more crude protein and
- 5–10 per cent less fibre (NDF) than is on offer.

**EXAMPLE 7.1:** Suppose a representative sample harvested from a pasture shows it to be:

10.2 MJ/kg DM, 17.4 per cent crude protein and 40 per cent NDF.

The pasture that cows select may be more like:
10.7–11.2 MJ/kg DM, 17.9–18.1 per cent crude protein and 36–38 per cent NDF.

The degree of selection and how it changes the feed value depends on grazing pressure (stocking rate) and availability of pasture. Cows can’t be so selective when stocking rates are high or pasture availability is low.

By using a ‘selection allowance’ developed from reliable research data, farmers can estimate what nutrients their cows are really getting from pasture.

### 7.2 Limitations of pasture

#### 7.2.1 Seasonal effects

Pasture growth varies throughout the year and is influenced by the growth pattern of the dominant pasture species and by grazing management.

Most perennial ryegrass/white clover pastures have peak growth in spring. Irrigation allows for extended periods of high pasture growth into the summer.

Management affects the quantity of pasture available at any particular time. Stocking rate is a major influence. At certain times of the year, pasture alone is unable to meet the nutritional requirements of the herd.

**Figures 7.4, 7.5, 7.6** show examples of typical growth patterns for ryegrass/white clover pastures in Gippsland, northern Victoria and western Victoria. The feed requirements for typical stocking rates and calving patterns are also shown.
Figure 7.4: Growth rate of ryegrass/white clover pasture in Gippsland and feed requirements at different stocking rates throughout the year.

Figure 7.5: Growth rate of ryegrass/white clover pasture in northern Victoria and feed requirements at different stocking rates throughout the year.
7.2 Calving pattern

Calving pattern affects pasture supply and demand. This is demonstrated in Figures 7.7, 7.8 and 7.9 where feed requirements for typical autumn- and spring-calving herds are superimposed on the average pasture growth rates for Victoria’s dairying regions.
Figure 7.7: Growth (G. Rate) of ryegrass/white clover pasture in Gippsland and feed requirements of herds calving in spring (Spr) and autumn (Aut).

Figure 7.8: Growth (G. Rate) of ryegrass/white clover pasture in northern Victoria and feed requirements of herds calving in spring (Spr) and autumn (Aut).
Figure 7.9: Growth (G. Rate) of ryegrass/white clover pasture in western Victoria and feed requirements of herds calving in spring (Spr) and autumn (Aut).

For a given stocking rate, feed requirements are similar despite different calving patterns. However, autumn-calving herds experience greater feed deficits in winter and consequently require more surplus feed to be conserved in spring.

Irrigation allows for the feed gaps in summer and autumn to be reduced to the point that deficits only occur in the late autumn-winter period.

7.3 Factors affecting pasture intake

A grazing cow’s performance depends largely on the nutrients she extracts from pasture. So we must consider the factors that influence the availability of nutrients from pasture, namely:

- the cow’s ability to harvest pasture; and
- the quality of the pasture eaten.

A number of things that affect intake relate to the cow herself. For example:

- cow size
- bite size
- bite rate
Chapter 7. Pasture Intake

- appetite
- stage of lactation; and
- pregnancy.

Feed itself can affect intake. For example:

- length of the pasture (long or short)
- amount of leaf, stem and dead material
- quality of the feed
- palatability of the feed
- species in the pasture (clover, grass, weeds; etc.); and
- contamination of the feed (mud, dung, urine).

7.3.1 The ability to harvest pasture

The intake of pasture is determined by:

- number of bites that the cow takes in a given time (rate of biting)
- amount of pasture harvested each bite (intake per bite)
- total time spent grazing (grazing time).

Pasture intake can be expressed as:

\[
\text{Pasture intake (kg DM/day)} = \text{Grazing time (mins/day) } \times \text{Rate of biting (bites/min) } \times \text{Intake per bite (kg/bite)}
\]

As grazing managers, you can exert some control over these factors.

7.3.2 Grazing time

The grazing day can be divided into three activities: grazing, ruminating and resting. Most grazing occurs during daylight. 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).

The pattern of grazing is undoubtedly affected by regular activities, such as milking or movement of stock on to different pasture types. Grazing time generally varies between 6 and 12 hours per day. It is unlikely that grazing time will extend beyond 12 hours. Average time spent grazing is about 8.5 hours, with 7–8 hours spent ruminating. As a rough ‘rule of thumb’:
A 500 kg cow offered sufficient pasture of optimal height (10 to 15 cm) and quality could eat about 17 kg DM in 24 hours, with a grazing time of approximately 8.5 hours.

Cows don’t eat continuously for 8.5 hours, but tend to graze for blocks of time. Consider this when using stand-off areas in conjunction with grazing of wet paddocks. On the right pasture, a cow can eat a fair proportion of her daily intake in two 3-hour grazings.

On short pasture, more grazing time is required to harvest closer to the ground. The time available for grazing can generally not be extended enough to fully compensate for lower availability. In other words, short pastures generally result in lower intakes.

7.3.3 Rate of biting

As grasses grow they develop different amounts of structural carbohydrate (stemmy material). The ‘toughness’ of this carbohydrate increases as the grass matures. It is harder to harvest stem than leaf, and mature stem is harder to harvest than young stem. So if a cow puts equal effort into harvesting pasture, then more leafy pasture can be eaten than stemmy pasture. (Very mature pasture is at the bottom of the scale.)

7.3.4 Intake per bite

Intake per bite is influenced by the amount of available pasture. Maximising feed intake depends on how the pasture is ‘presented’ to the cow; for example, the allowance and availability of pasture.

Allowance

Allowance is simply the quantity of pasture (kg DM) made available to each cow. Pasture intake increases as pasture allowance per cow increases, although a point will be reached where offering more feed will not increase intake.

For a good daily intake of pasture your cows should be offered more than they can eat in a day. Offering a lot will also allow the cow to select a higher quality diet. This increases both the rate of digestion and intake.

However, cows should not be offered so much pasture that waste occurs and causes pasture quality to decline.
Remember, too, that a lot of the pasture on offer is close to ground level where it is difficult to harvest.

**Availability**

Availability is determined by the pasture cover (kg DM/ha). The intake per bite will be greater from a 10 cm-tall pasture spread over one hectare than from a 1 cm-tall pasture spread over 10 hectares. The total quantity of pasture on offer might be the same, but the longer pasture is more available. It is easier to get a mouthful of long pasture than of short pasture.

**7.3.5 The effect of pasture quality**

One of the main effects of pasture quality is on the rate at which it is broken down by the rumen microbes. High quality pasture is quickly broken down and passed further along the digestive system where nutrients are absorbed. Poor quality pasture is more fibrous and therefore takes longer to break down and pass out of the rumen.

The more quickly pasture is processed and moved out of the rumen, whether to be absorbed or passed out as faeces, the sooner more pasture can be eaten to fill the rumen again.

Better quality pasture will result in higher intakes, but there is a second benefit of providing good pasture. Higher quality pastures are more digestible and so can offer more nutrients per kg of dry matter than poorer quality pastures.

**Palatability**

Cows eat more of what they like and less of what they don’t like. They don’t like soiled pasture (such as you might find in night and sacrifice paddocks), mature pastures (stemmy and dead plants) or weeds, and they do like clover and young succulent grass.

In practice it is important to find ways to offer your cows pastures that are:

- leafy (highly digestible);
- of moderate to tall height (easy to harvest);
- very palatable (uncontaminated young succulent plants).

If you do, your cows will have high intakes, digest more of the nutrients and produce more.
Seasonal effects

Pasture changes; in any given season, pasture quality and hence pasture intake can be influenced by management. It is the management of pastures within the season rather than the season itself that affects intake of pastures.

7.4 Getting the best from pasture

This section presents practical ideas for getting the best intake of pasture by grazing cows. We identify why cows graze the way they do.

7.4.1 Characteristics of a good pasture

Pasture should be:

- *Easily grazed:* Harvesting short pasture is hard work, so make sure there is reasonable length (10–15 cm)

- *Leafy:* Leaf is the most easily digested part of the plant and has the most nutrients (energy and protein)

- *Free of stem:* Stem is harder for a cow to graze; it is tougher than leaf and harder to bite off. It contains less digestible nutrients than leaf and is broken down slowly. The cow will not ‘fill up’ as often on stemmy feed

- *Free of decaying material:* Cows don’t like compost. They eat less if the pasture contains decaying leaves and stem

- *Full of clover and ryegrass:* These are the most nutritious pasture species we can easily grow. Cows find them very palatable.

To get a ‘good pasture’ like this, you need to graze it to approximately 4 cm height and allow it to grow back to the ‘3-leaf stage’ (three ryegrass leaves per tiller – refer to the Target 10 Pasture Management Course).

If a lot of pasture remains after grazing, there will be old, decaying leaves by next grazing. You don’t want this.

If pasture gets tall, it will 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 of what you are after in pastures at future grazings: quality leaf material.
7.4.2 Dealing with dung patches

Dung patches are a curse for pasture managers who strive for perfection. The patches develop into clumps that are not palatable to stock and so present problems with stem, dead leaves and shading. There are some options for improving management of clumps in pasture.

- **Remove them mechanically (mower or topper).** This does a good job but takes time and expense.

- **Use a class of stock other than milkers to eat the clumps.** This will do a fair job but has a few problems associated with it. For example, stock will over-graze between clumps before eating out well. Regrowth will be slowed considerably. Also, to do the job well, the stock need to be hungry. Low intake will result in poor animal performance. Can you justify doing this to your stock?

- **Try to closely match available pasture with cow requirements.** When the two are well matched, you will notice cows graze the clumps a little each time and prevent them from getting out of control. In addition, dung produced by cows eating quality feed is easily broken down by soil organisms. The taint goes quickly (a couple of rotations) and cows resume normal grazing.

While dung is loose on lush feed, low quality feeds (e.g., stemmy hay) produce dung pads that dry like a mud brick and stay around for months. These cause a lot of problems with pasture clumping.

You can’t prevent clumping but you can manage the effect so it doesn’t become a big problem.

7.4.3 Height of grazing

Another practical tip for getting consistent intakes is not to require the cow to graze below the previous height of grazing (or cutting). The pasture below this height will contain a lot of dead or decaying plant plus a lot of stem; neither of these are good for high production. To ensure good grazing next time, make sure you leave the pasture in the recommended condition.
8. Best Use of Pastures

Pasture is by far the cheapest feed source on the dairy farm, so it should be made full use of before costly supplements are brought in.

However, pasture growth rate changes considerably according to the season. There are periods of the year when pastures will not fully meet cow requirements.

In this chapter, we discuss maximising pasture performance regardless of the season, or the stocking rate and calving pattern. The material in this chapter demonstrates how to roughly quantify amounts of pasture available and consumed.

8.1 Principles behind pasture utilisation

The secret to maximising pasture yield and quality is to:

- allow pasture species to develop to optimal growth potential between grazing; and
- harvest mainly leafy material.

8.1.1 Allow the pasture to grow well

If pastures are allowed sufficient time after grazing to grow back to a suitable grazing condition, then you can be confident that the pastures are growing as well as they can (see also Target 10: Pasture Management for Dairy Farmers).

‘Pasture wedge’

In an ideal world we should offer 10–15 cm high pastures to our cows every day. Yesterday’s pastures should be 3–4 cm high after grazing.

When pastures are grazed in rotation there will be gradation in pasture heights between these two heights. This profile of pasture heights on the farm is known as the ‘pasture wedge’.

The challenge is to maintain the ‘pasture wedge’ for as much of the year as possible. This will guarantee the
quality of pasture as a feed because it will be mainly leaf. Once developed, ‘the wedge’ can only be maintained by choosing the correct allocation of pasture each day.

**Allocating pasture**

The correct allocation of pasture depends primarily on the pasture growth rates. You also need to know the total grazed area and the paddock sizes.

When pasture growth is slow, the allocated area of pasture may fall short of the needs of the livestock. However, when pastures grow well the cows’ daily pasture needs may be exceeded.

Total grazed area can then be reduced by closures for silage or hay making while still allocating a sufficient area of pasture to meet requirements.

Pasture is correctly allocated when the area of pasture offered each day provides the same amount of pasture that has grown on the whole grazed area that day.

### 8.2 Essential tools for pasture allocation

#### 8.2.1 Pasture growth rates

Current growth rates are the major determinant of the area provided for grazing. It is difficult to have a good appreciation of actual growth rates but average figures for your region can be a good starting point.

#### 8.2.2 Available pasture

Until you develop the skills to assess pastures well, some approximate ‘rules of thumb’ may help.

For example we may assume that:

- 10–15 cm high pasture (pasture ready for grazing) = 2200 kg DM/ha
- 3–4 cm high pasture (residual pasture after grazing) = 1300 kg DM/ha

A grazed hectare of 10–15 cm high pasture should provide approximately 900 kg DM (2200 kg DM - 1300 kg DM).
8.3 Calculating the correct allocation

The correct daily allocation of pasture should not alter the ‘pasture wedge’ because it is equivalent to the total amount grown on the total grazed area each day.

In other words:

\[
\text{kg DM from the area allocated for grazing} = \frac{\text{kg DM grown on total grazed area}}{900}\text{ kg DM/ha} \times \text{Total grazed area (ha)}
\]

The ‘correct’ area of pasture to offer stock each day can be calculated using the following formula:

\[
\text{Area to allocate for grazing (ha/day)} = \frac{\text{Pasture growth rate (kg DM/ha/day)}}{900}\text{ kg DM/ha} \times \text{Total grazed area (ha)}
\]

**EXAMPLE 8.1**

Suppose typical daily pasture growth in autumn is 20 kg DM/ha and the total grazed area is 60 ha.

The appropriate area to offer grazing stock each day would be:

\[
20 \text{ kg DM/ha/day} \div 900 \text{ kg DM/ha} \times 60 \text{ ha} = 1.3 \text{ ha/day}
\]

So, figures for average pasture growth rates in your area will allow you to develop a plan to maximise pasture performance and help to minimise reliance on supplements (see Exercise 8.1).

**EXERCISE 8.1:** Use the pasture allocation formula to calculate the daily grazing allocation for your farm throughout the year. (Your presenters will provide pasture growth rates typical for your area.) The growth rates used are examples only for your area and are used as a guide. Actual figures may be very different.
Chapter 8. Best Use of Pastures

<table>
<thead>
<tr>
<th>Month</th>
<th>Average daily pasture growth (kg DM per ha)</th>
<th>Area that this represents on your farm (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
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<tr>
<td>May</td>
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<tr>
<td>June</td>
<td></td>
<td></td>
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<tr>
<td>July</td>
<td></td>
<td></td>
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<tr>
<td>August</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remember that this is a very simple example. On a real farm the milkers are likely to share the total area available for grazing with other stock.

8.4 How well does allocated pasture meet cow requirements?

Now you are able to estimate the pasture eaten by each cow.

For example, take the situation of 80 milkers on 60 ha, in autumn. The average pasture growth rate is 20 kg DM per ha.

As you worked out above, in order to maintain a ‘pasture wedge’ on the farm, no more than 1.3 ha should be offered each day.

Therefore:

Daily pasture consumption for the herd is:

\[ 900 \text{ kg DM/ha} \times 1.3 \text{ ha} = 1,170 \text{ kg DM} \]

and each cow is eating:

\[ 1,170 \text{ kg DM} \div 80 \text{ milkers} = 14.6 \text{ kg DM per cow} \]
If the energy density of the pasture is 10–11 MJ/kg DM, multiply the energy density by the dry matter intake from pasture.

The result is that each cow in the example has an approximate daily intake of 146 to 160 MJ ME.

8.5 Practical implications

8.5.1 When pasture does not meet cow requirements

Too little pasture

The shortfall in feed requirements is the difference between pasture growth and feed requirements. It is possible to make up for this shortfall by careful use of more costly supplements.

Too much pasture

The amount of excess pasture can indicate the proportion of the farm that could theoretically be set aside for silage or hay.

For example, if your cows require 160 MJ/day and the area allocated daily would provide 200 MJ/day, you are providing 25 per cent more pasture than necessary.

In other words, you could reduce your total grazed area by 25 per cent. A quarter of the farm could be set aside for fodder conservation.

8.5.2 Simple monitoring of the farm

Once you recognise the quantity and quality of pasture that is appropriate for your cows, it can be quite simple to work out how much pasture to allocate to grazing.

If there does not seem to be any pasture that will be a leafy 10 to 15 cm by the time it is needed, then too much pasture is being offered each day. In other words stock is being moved too quickly about the farm.

On the other hand, you might have a lot of paddocks that will be more than 10–15 cm high by the time they are required. In this case you may be moving too slowly through the rotation and offering too little pasture each
day. Or, you may be feeding supplements unnecessarily when you could be feeding pasture.

Perhaps some of your paddocks have reached the stage when they should be ‘dropped out’ for conservation.

**8.5.3 Pugging**

At times of the year when pasture growth is slow, the recommended allocation is also low and the herd grazes over a small area each day. In wet conditions this may cause pugging and destroy soil structure.

Pugging needs to be avoided, but offering larger areas for grazing will rapidly reduce the growth potential of the pastures. There are better solutions.

One practical option may be to operate with taller pastures during wet winters. This lets cows get their daily intake of pasture quicker and they can then be moved to a sacrifice or ‘off-pasture’ area for feeding of supplements.

There may be some loss of quality in the longer pasture, but this should be made up for by a reduction in pugging.

**8.5.4 Dry conditions**

In long dry spells without irrigation, pastures cannot be expected to grow effectively. Then, the idea of restricting the area grazed each day to what our formula dictates is probably impractical.

If occasional showers or a seasonal ‘break’ are expected, a rotational grazing regime will ensure that some of the farm will be more responsive to the change in conditions.

Once conditions change to allow pasture growth, the challenge is to establish a slow rotation, or daily allocation, and to feed supplements and thus re-establish the pasture wedge and the associated benefits in pasture growth.

**8.5.5 Feed planning**

In Exercise 8.1, the background for a feed plan was set out. A feed plan can be likened to maintaining the balance of a bank account. Pasture growth is the deposit and demand for pasture by your cows is the withdrawal.
Chapter 8. Best Use of Pastures

The pasture wedge is the balance that you want to maintain.

**EXERCISE 8.2: Develop a simple feed plan.**

*To do this, use:*

- **Answers from Exercise 8.1**
- **Details of your own farm**
- **Methods to calculate cow requirements set out in Chapters 5, 6.**

<table>
<thead>
<tr>
<th>Month</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D = (C - B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area allocated each day (ha) (Exerc. 8.1)</td>
<td>Energy supplied each day from pasture (MJ ME)</td>
<td>Daily energy requirement (MJ ME)</td>
<td>Energy needed from supplements (MJ ME)</td>
</tr>
<tr>
<td>Jan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Column A:** Use the allocations you calculated in Exercise 8.1.

**Column B:** Column A x 900 x energy density of the pasture.

**Column C:** Use details of your farm and herd, with Worksheet 1, to calculate the energy requirements of your cows throughout the year.

**Column D = Column C - B** (energy deficit to be made up with supplements).
Estimating your requirement for supplemented energy in advance allows you to anticipate how much extra feed your cows will need and to plan how to provide it.

Your presenters will provide estimates of the energy density of pastures in your area throughout the year.
9. Supplements

This chapter addresses some practical and nutritional considerations involved in the use of different supplements.

The final section explains how to check whether the proposed diet is balanced for energy, protein and fibre.

9.1 Choice of supplement

A number of supplements can be fed to dairy cattle. The decision to use a certain supplement is determined by a combination of factors, including:

- **What is the limiting nutrient?** Energy, protein, fibre, or a combination of all three due to low pasture intake?
- **What supplements are available?**
- **What is their nutritive composition?**
- **What are the relative costs?**
- **What are the practical implications?** E.g. facilities for storage and feeding, machinery for feeding out, labour requirements, reliability of supply, and so on?
- **What are the nutritional implications?** How will the supplement affect the ration balance; could problems such as acidosis arise?

In a pasture-based system, energy is normally the first limiting nutrient. Therefore, in most cases, supplements should be compared on the basis of cents per MJ.

The lower the cost per megajoule supplied, the cheaper the supplement. It is also possible to cost supplements on the basis of cents per gram crude protein supplied, or cents per gram neutral detergent fibre.

9.1.1 Defining the nutritive value of supplements

Supplements are classified by their ability to supply additional energy, protein, fibre or vitamins and minerals to dairy cows. They come in the form of concentrates, conserved fodder, fodder crops or by-products.
Most tables of feed composition report only the average energy and protein contents. Yet, there can be large variations within any type. For example, plant-derived feeds may vary with season of growth, soil type, and crop management.

When developing diets, it is important to know the qualities of the individual feeds that make up the diet.

### 9.1.2 Calculating the nutritive value of supplements

To categorise feeds based on their composition, we have used values derived from the FEEDTEST service and others collected from Australia-wide surveys.

The values are presented in Tables 9.2, 9.3, 9.4, and 9.6 later in this chapter. The tables list the average values and ranges for dry matter (DM%), energy (MJ/kg DM), crude protein (CP%) and neutral detergent fibre (NDF%).

*Appendix D* also provides a list of feed values for various feeds.

Tables 9.2, 9.3, 9.4, and 9.6 also estimate undegradable dietary protein (UDP) supply according to the categories listed in Table 9.1. Australian data is at present insufficient, so the categories are based on worldwide results.

<table>
<thead>
<tr>
<th>Category</th>
<th>UDP</th>
<th>RDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (H)</td>
<td>more than 69%</td>
<td>less than 31%</td>
</tr>
<tr>
<td>Good (G)</td>
<td>69–50%</td>
<td>31–50%</td>
</tr>
<tr>
<td>Moderate (M)</td>
<td>49–30%</td>
<td>51–70%</td>
</tr>
<tr>
<td>Poor (P)</td>
<td>29–10%</td>
<td>71–90%</td>
</tr>
</tbody>
</table>

When discussing the requirements of cows and composition of feeds, this manual concentrates on energy, protein and fibre. The following sections cover energy, fat and protein supplements, conserved forage and fodder crops and the nutritive value of each type of feed.
9.2 Energy supplements

9.2.1 Types of energy supplements

Feeds with large quantities of starches and sugars (e.g., cereal grains and some by-product feeds) are used as energy supplements. Barley, triticale, wheat and oats are the most commonly fed cereal grains. Energy can also be supplied by commercial concentrate pellets, specially formulated concentrate mixes, or by-products. Analyses of some energy-rich supplements are presented in Table 9.2.

Table 9.2: Nutritive value of some common energy-rich supplements.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (%)</th>
<th>Energy (MJ/kg DM) Average (Range)</th>
<th>Crude protein (% of DM) Average (Range)</th>
<th>UDP supply (% of DM)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal grains</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>90</td>
<td>12 (12–14)</td>
<td>12 (8–18)</td>
<td>P</td>
<td>20</td>
</tr>
<tr>
<td>Wheat</td>
<td>90</td>
<td>13 (12–14)</td>
<td>12 (9–17)</td>
<td>P</td>
<td>14</td>
</tr>
<tr>
<td>Oats</td>
<td>90</td>
<td>11 (9–13)</td>
<td>10 (6–13)</td>
<td>P</td>
<td>32</td>
</tr>
<tr>
<td>Triticale</td>
<td>90</td>
<td>13 (12–13)</td>
<td>12 (8–16)</td>
<td>P</td>
<td>14</td>
</tr>
<tr>
<td>Maize</td>
<td>90</td>
<td>14 (12–16)</td>
<td>10 (7–14)</td>
<td>M</td>
<td>9</td>
</tr>
<tr>
<td>Sorghum</td>
<td>90</td>
<td>11 (7–13)</td>
<td>11 (6–15)</td>
<td>M</td>
<td>18</td>
</tr>
<tr>
<td>Commercial pellets</td>
<td>90</td>
<td>12 (11–13)</td>
<td>14 (12–16)</td>
<td>M</td>
<td>15</td>
</tr>
<tr>
<td>By-product feeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole cottonseed</td>
<td>90</td>
<td>15 (13–16)</td>
<td>24 (20–26)</td>
<td>M</td>
<td>44</td>
</tr>
<tr>
<td>Wet brewers grain</td>
<td>25</td>
<td>10 (9–12)</td>
<td>23 (21–27)</td>
<td>M</td>
<td>42</td>
</tr>
<tr>
<td>Carrots</td>
<td>12</td>
<td>13 (12–14)</td>
<td>9 (8–15)</td>
<td>–</td>
<td>12</td>
</tr>
<tr>
<td>Potato mash</td>
<td>24</td>
<td>14</td>
<td>7</td>
<td>–</td>
<td>12</td>
</tr>
<tr>
<td>Citrus pulp</td>
<td>18</td>
<td>12 (10–13)</td>
<td>7 (6–8)</td>
<td>P</td>
<td>23</td>
</tr>
<tr>
<td>Whey</td>
<td>7</td>
<td>14</td>
<td>11</td>
<td>P</td>
<td>-</td>
</tr>
</tbody>
</table>

Commercial pellets often contain more UDP than do their ingredients. The high temperatures used to manufacture commercial feed pellets alter the protein and protect it from breakdown in the rumen.

Apart from oats and sorghum, the energy content of cereal grains is fairly consistent, although protein levels may vary widely. Cereal grains, except maize and sorghum, are generally a poor source of UDP.

Most cereal grains are low in calcium, which may be important if feeding high grain levels during early lactation when milk fever is a potential problem.
Many of us take for granted that we know how much grain cows are actually eating.

If you have in-shed feeders it is recommended that you check them at least once per year. It is not uncommon for individual feeders to be out by as much as a kilogram when dispensing 4–5 kg of grain.

Acidosis is caused by a build-up of lactic acid in the rumen as a result of feeding high levels of cereal grains or suddenly increasing the amount of grain in the diet. Increased acidity reduces the activity of the microbes that break down fibre, which results in slower digestion and reduced appetite.

If acidosis occurs and only a few cows are affected, check the feeders before you do anything else.

**9.2.2 Milk responses to energy supplements**

Milk responses to supplementary feeding vary widely. The responses depend on stage of lactation, quality of supplement, pasture quality, pasture substitution and stocking rate.

**Stage of lactation**

With energy supplements, responses can be up to 1.6 L milk/kg DM of supplement fed in early lactation. Late in the lactation cycle, response can be up to 0.7 L milk/kg DM of supplement fed.

This is the theoretical expectation, but probably only applies when feed ingredients are similar at both stages of lactation.

Trials at Kyabram Dairy Centre have shown that the quality of the pasture may affect the milk response to supplements.

The best milk responses are seen in summer and autumn, when pastures provide little energy because they are dominated by paspalum and other poor quality species.

**Quality of supplement**

A recent summary of grazing and pen-feeding trials conducted at Kyabram showed that milk responses to a wide range of supplements were closely related to their
metabolisable energy (ME) content, regardless of the type of supplement (R. Stockdale, pers. comm.).

This summary compares the milk responses to cereal grain, maize silage and hay.

On average, responses were:

<table>
<thead>
<tr>
<th>Type</th>
<th>Response</th>
<th>Ingredient Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.4 L/kg DM</td>
<td>hay containing 8.8 MJ/kg DM,</td>
</tr>
<tr>
<td>Medium</td>
<td>0.9 L/kg DM</td>
<td>maize silage containing 10.1 MJ/kg DM,</td>
</tr>
<tr>
<td>High</td>
<td>1.6 L/kg DM</td>
<td>cereal grains containing 12 MJ/kg DM.</td>
</tr>
</tbody>
</table>

9.2.3 Pasture quality and pasture substitution

If cows in early lactation are only offered limited pasture, it is possible to produce 1.5 litres of milk for every kilogram of supplement DM fed out.

An average response over the full lactation is 1.0 litre of milk per kg of supplement DM fed. If cows are provided with excess pasture they may reduce their pasture intake when offered supplements. This is referred to as pasture substitution. In this case, milk responses to substitution may only be 0.5 litres of milk/kg DM supplement fed, or even less.

High quality pastures sometimes contain so little dietary fibre that feeding large amounts of concentrates, say more than 4–5 kg/day, can reduce milk fat content and lead to digestive upsets (e.g. acidosis). Rumen buffers should then be fed to maintain normal rumen function.

With poor quality pastures, these problems tend not to occur when concentrates are fed because the pastures contain enough fibre. However, poor quality pastures combined with concentrates low in protein may lead to a protein shortfall which reduces the milk yield response to supplementation. It is therefore important to know the energy density and protein content of supplements.

When feeding up to 5 kg of supplements daily per cow, most trials have found milk production responses to be similar, regardless of the type of cereal grain or pellets fed.

This is because the energy intake from the supplement contributes only a small proportion of the total daily energy intake of grazing cows. When fed supplements, the...
cow’s appetite for pasture can vary widely depending on grazing pressure, pasture quality and substitution of the supplement for pasture.

Feeding low levels of cereal grains or commercial pellets leads to equivalent responses in milk production, but the situation may be different with high levels of supplement feeding.

Cows are able to eat more pellets than grain because of the inclusion of rumen buffers to prevent acidosis. Furthermore, pellets constitute a better balanced feed while combinations of pasture and cereal grain may lead to nutrient deficiencies, especially if the composition of the cereal grain is not known.

9.3 Fat supplements

Fats are concentrated forms of energy, containing up to 35 MJ/kg DM. Some farmers incorporate cooking fats or tallow into cereal grain-based concentrates. Milk responses to fat supplements can be in the order of 3 litres of milk and 0.3 per cent rise in fat test for each kilogram of fat consumed.

Since December 1996, feeding ruminants feeds sourced from ruminants has been banned.

Fats that are present in the rumen may coat fibre in the diet, and can reduce fibre digestion if dietary levels are too high. The upper limit for dietary fat concentration is about 5 per cent of total dry matter.

Bypass fats which are digested in the small intestine can be fed at higher levels without these side effects. However they are very expensive, up to $950/tonne. They should only be fed during early lactation to high yielding cows (greater than 30 L/day). Such cows may otherwise lose weight so quickly that their fertility and metabolism may be upset.

There is an upper limit to the use of bypass fat due to the animal’s limited ability to digest the fat in the lower digestive tract. When using bypass fat, total fat in the diet should not exceed 7 per cent, with the fat coming from:

- 1/3 plant source
- 1/3 vegetable oil
- 1/3 bypass fat.
9.4 Protein supplements

9.4.1 Types of protein supplements

Table 9.3: Nutritive value of some common protein-rich supplements.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (%)</th>
<th>Energy (MJ/kg DM) Average (Range)</th>
<th>Crude protein (% of DM) Average (Range)</th>
<th>UDP supply (%)</th>
<th>NDF (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>100</td>
<td>0 -</td>
<td>250* -</td>
<td>Nil</td>
<td>0</td>
</tr>
<tr>
<td>Grain legumes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lupins</td>
<td>90</td>
<td>13 (12-13)</td>
<td>33 (28-40)</td>
<td>P</td>
<td>27</td>
</tr>
<tr>
<td>Peas</td>
<td>90</td>
<td>13 (12-13)</td>
<td>24 (20-27)</td>
<td>P</td>
<td>13</td>
</tr>
<tr>
<td>Animal protein meals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td>85</td>
<td>12 (10-13)</td>
<td>67 (65-70)</td>
<td>H</td>
<td>7</td>
</tr>
<tr>
<td>Vegetable protein meals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>85</td>
<td>13 (12-14)</td>
<td>52 (46-59)</td>
<td>M</td>
<td>15</td>
</tr>
<tr>
<td>Safflower</td>
<td>85</td>
<td>11 (9-12)</td>
<td>43 (22-54)</td>
<td>M</td>
<td>58</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>85</td>
<td>12 (11-13)</td>
<td>42 (37-45)</td>
<td>M</td>
<td>30</td>
</tr>
<tr>
<td>Canola</td>
<td>85</td>
<td>12 (11-13)</td>
<td>39 (33-43)</td>
<td>P</td>
<td>28</td>
</tr>
<tr>
<td>Sunflower</td>
<td>85</td>
<td>10 (6-12)</td>
<td>35 (26-50)</td>
<td>M</td>
<td>40</td>
</tr>
<tr>
<td>Linseed</td>
<td>85</td>
<td>12 -</td>
<td>34 (30-40)</td>
<td>M</td>
<td>-</td>
</tr>
</tbody>
</table>

*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 CP % of over 100.

The nutritive values of some protein-rich supplements are presented in Table 9.3. These include urea, grain legumes, and animal and vegetable protein meals.

Urea is a common source of nitrogen, but it is not a protein. It has no energy value and is potentially 100 per cent rumen degradable. It is mainly used 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. It is recommended that urea only be fed to animals that have a fully functioning rumen and at a maximum rate of 1 per cent of total dry matter intake.
Grain legumes are multi-purpose; they are good sources of both protein and energy. However, their protein is very degradable in the rumen.

Fish meal has the highest supply of UDP and a good balance of amino acids for milk production. However, it is very expensive, costing upwards of $900/tonne.

Protein meals from plants generally have only moderate levels of UDP. The amino acids supplied in the protein of oil seed meals do not match the requirements of lactating cows as well as the amino acids supplied from animal sources.

Energy levels of all the protein meals are comparable to those of cereal grains.

9.4.2 Milk responses to protein supplements

Good milk responses to protein supplements can only be obtained if they are used to overcome an actual protein deficiency. Otherwise, they are broken down and used inefficiently as an expensive energy supplement.

Good responses to protein supplements have, however, been recorded in high-yielding herds (greater than 30 litres/day at peak) where large amounts of additional energy were also fed in early lactation.

Research from Ellinbank (Dalley et al., 1997) and Queensland (Moss et al., 1995) has concluded that when sufficient energy is supplied to support milk production in excess of 30 L/day, then the form of the protein is not important, provided that the total protein requirements of the animal are met.

If protein is provided in excess of requirements, or insufficient energy is available to utilise the dietary protein, then milk production can suffer.

Energy is required to remove the excess protein from the body. In high producing cows grazing pasture during early lactation, production penalties of up to 0.7 L milk have been measured for each percentage unit of protein in the concentrate above 18.5 per cent (Dalley et al., 1996). In this instance the protein was supplied by cottonseed meal in a pelleted barley concentrate.
Extra protein is often fed together with energy supplements during the summer and autumn when protein levels are low in both the pasture and many of the cereal grains and turnip supplements fed at these times of the year.

Milk production responses have been recorded to both RDP and UDP supplementation, but only with RDP supplements does the increased milk production exceed the cost of supplementation (Moate et al., 1997).

Lupins, cottonseed meal and canola meal are the most popular protein grains fed in Victoria. They are relatively cheap, readily available, palatable, and a good source of RDP.

Price and availability of the different protein meals vary widely during the year. If there is a need to feed a high-protein feed, the choice should be based on the cost per unit of crude protein and possibly also the supply of UDP, although the latter depends on the pasture supply and quality and the stage of lactation.

9.5 Processing energy and protein supplements

9.5.1 Processing grains

Feeding whole, unprocessed cereal grains generally leads to lower utilisation of the supplement and lower milk responses. This is because the grains do not spend sufficient time in the rumen for microbes to break through their seed coat.

Oats are an exception to this rule. Trials have found little difference in milk responses to whole or processed oats.

The optimum amount of processing gives acceptable and maximum digestibility. Further processing only causes additional interference with digestion.

The most common forms of on-farm processing currently used in Australia are rolling and hammer milling. Other forms of processing are carried out on a larger scale by feed manufacturers and include chemical processing, pelleting, and heating.
Rolling 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 are broken into three or four pieces.)

Increasing the degree of rolling or hammer milling makes the grain starch more readily available in the rumen. This improves utilisation. But it may result in digestive problems if high levels of grain (above 4 kg/cow/day) are fed. It may also depress the milk fat test.

Fine grinding of grain can also reduce its palatability to cattle.

Chemical processing

Treating grains with an alkali such as sodium hydroxide has also been investigated. This 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.

However, using an alkali such as sodium hydroxide may lead to problems in handling the grain. Treated grain may solidify.

Other methods, like using ammonia to treat grain, can reduce these handling problems while providing the same benefits as the alkali treatment.

Pelleting and heat treatment

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

At high levels of supplementary feeding, pellets can have an advantage over grains because they contain rumen buffers to prevent acidosis and they may be better balanced for energy and protein. Feeding trials have indicated little difference in terms of milk production when pellets and cereal grains have been compared (J. Moran, pers. comm.).
9.5.2 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 per cent improvement in digestibility.

Heat or chemical treatment (e.g. formaldehyde) of feeds high in protein can reduce their degradability in the rumen (i.e. increase the bypass effect).

However, 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.

9.6 Conserved forage supplements

9.6.1 Types of conserved forages

Conserved forages are generally high in fibre. They can also be valuable energy and protein supplements (Table 9.4).

The higher values in the energy and crude protein values tend to be found in early-cut hay and silage. Lower values indicate energy and protein values for late-cut hay and silage.

Table 9.4 also lists typical dry matter (DM) and undegradable dietary protein (UDP) contents of conserved forages. Appendix E provides some information on hay and silage bale weights, dry matter content of bales and dry matter per bale.
### Table 9.4: Nutritive value of some conserved forages.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (%)</th>
<th>Energy (MJ/kg DM) Average (Range)</th>
<th>Crude protein (% of DM) Average (Range)</th>
<th>UDP supply</th>
<th>NDF (of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne hay/silage</td>
<td>20-80*</td>
<td>8 (7–9)</td>
<td>16 (14–20)</td>
<td>M/P</td>
<td>40–60</td>
</tr>
<tr>
<td>Legume-based hay/silage</td>
<td>20-80*</td>
<td>9 (5–12)</td>
<td>17 (5–26)</td>
<td>M/P</td>
<td>35–55</td>
</tr>
<tr>
<td>Oaten hay</td>
<td>85</td>
<td>8 (6–10)</td>
<td>9 (9–17)</td>
<td>P</td>
<td>50–60</td>
</tr>
<tr>
<td>Maize silage</td>
<td>35</td>
<td>10 (9–11)</td>
<td>6 (5–8)</td>
<td>P</td>
<td>40–55</td>
</tr>
<tr>
<td>Sorghum silage</td>
<td>35</td>
<td>8 (7–9)</td>
<td>6 (5–8)</td>
<td>P</td>
<td>50–60</td>
</tr>
<tr>
<td>Oaten straw</td>
<td>85</td>
<td>6 (5–7)</td>
<td>3 (2–4)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Barley straw</td>
<td>85</td>
<td>6 (5–8)</td>
<td>3 (2–5)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Rice straw</td>
<td>85</td>
<td>6 (5–7)</td>
<td>4 (3–5)</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

* Hay – 80–85%, round bale silage – 40–80%, pit silage 20–40%

The traditional supplement for dairy cows was pasture hay, conserved from excess pasture growth of the preceding spring. Its low and variable quality generally gave poor milk production responses. Consequently, farmers now feed milkers a combination of silage and high-energy or -protein supplements. Hay or silage is often seen as a suitable supplement only for dry cows or young stock. However, if high-quality pasture hay or silage can be made or purchased consistently, it can be used to overcome feed shortages in summer and autumn pastures. The two roughages can have similar nutritive values.

High-quality conserved forages such as pasture silage can also provide the necessary fibre and protein to balance the diet. 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 higher.

Table 9.5 shows some typical ranges of feed qualities for hays and silages from grass and legume pastures in western Victoria.

Pasture silage is generally higher in nutritive value than hay. Therefore, milk responses to pasture silage should be better than to hay.
Table 9.5: Quality of conserved pasture hay and silage from western Victoria.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Energy (MJ/kg DM)</th>
<th>Crude protein (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>Pasture hay</td>
<td>8.5</td>
<td>6–9.5</td>
</tr>
<tr>
<td>Pasture silage</td>
<td>9.5</td>
<td>8–10.5</td>
</tr>
</tbody>
</table>

(Source: J. Jacobs, pers. comm.)

However, during fermentation of 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.

High-yielding cows (producing more than 30 L/day) supplemented with silage may require extra UDP, from a protein meal for instance.

Maize silage must be harvested at the correct stage of maturity to achieve maximum dry matter yield and quality. This is because the grain that develops in the cob compensates for increasing fibre levels in the stalk and leaves.

When there is a shortfall of good quality pasture in spring, maize silage (energy average 10–10.5 MJ/kg DM) can promote good milk responses because the pasture has a high protein content then.

The low protein content of maize silage means additional protein supplements are needed if it is fed in large quantities to grazing cows in autumn when the protein content of pasture is low. The protein in the supplements should be of high amino acid quality.

### 9.6.2 Processing conserved forages

Chopping hay or silages into smaller pieces to increase intake does not lead to any worthwhile increase in milk production.

However, treating straws or hays with a chemical such as sodium hydroxide may improve digestibility. This treatment can cause some of the more indigestible lignin to be broken down in the rumen. It is, however, a costly practice and sodium hydroxide can be corrosive to machinery.
9.6.3 Stage of maturity and nutritive value of conserved forages

The stage of maturity of conserved pasture has a considerable effect on its energy value. In a study conducted in western Victoria, silage cut on 5 October contained 11.3 MJ/kg DM (Figure 9.1). Perennial pasture was still in its vegetative, pre-flowering stage of growth at this time. The energy density remained above 11 MJ/kg DM until the last week of October.

![Graph showing typical changes in nutritive value of silage as pasture matures.](source: Jacobs et al., 1998)

**Figure 9.1:** Typical changes in nutritive value of silage as pasture matures.

At this point ear emergence occurred in the ryegrass fraction of the sward and energy values declined thereafter. Clearly, any pasture conserved too late in the season would be of little benefit to milkers because of its lower energy density.

9.7 Fodder crop supplements

In Victoria, fodder crops have become an important supplement to pastures over summer and autumn. Some dairy farmers have also sown fodder crops in autumn to try to fill the winter feed gap. **Table 9.6** lists the most common fodder crops grown in Victoria and their feed values, where available.
Table 9.6: Nutritive value of some commonly grown fodder crops.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (%)</th>
<th>Energy (MJ/kg DM) Average (Range)</th>
<th>Crude protein (% of DM) Average (Range)</th>
<th>UDP supply</th>
<th>NDF (% of DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnips, whole</td>
<td>10</td>
<td>13 (11–13)</td>
<td>11 (6–18)</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Turnips, leaf</td>
<td>9</td>
<td>12 (4.5–11)</td>
<td>14 (8–20)</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Turnips, root</td>
<td>11</td>
<td>13 (13–14)</td>
<td>9 (6–15)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Rape</td>
<td>14</td>
<td>12</td>
<td>20</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Pasja</td>
<td>14</td>
<td>13</td>
<td>20</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td>18</td>
<td>9</td>
<td>11</td>
<td>P 40–60</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>18</td>
<td>9 (7–11)</td>
<td>12 (7–18)</td>
<td>P 40–60</td>
<td></td>
</tr>
<tr>
<td>Oats, flowering</td>
<td>23</td>
<td>9</td>
<td>8</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Oats, immature</td>
<td>16</td>
<td>10 (9–12)</td>
<td>21 (20–24)</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Maize, tassel stage</td>
<td>19</td>
<td>10</td>
<td>11</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Typical annual ryegrass</td>
<td>16</td>
<td>11 (9.5–11)</td>
<td>22 (18–24)</td>
<td>30–45</td>
<td></td>
</tr>
</tbody>
</table>

The most common fodder crops grown in southern Victoria are turnips and, to a lesser extent, maize and rape.

Turnips in particular are high in energy and can be used like a concentrate when fed to cows. They are relatively cheap to grow and can yield 7–9 tonnes DM/ha when sown in mid to late October. The fibre content of turnips may be low, and if fed with a cereal grain there could be insufficient fibre and protein levels in the total diet.

Trials at Ellinbank Dairy Research Institute indicate that the protein content of turnips may be borderline (P. Moate, pers. comm.). Feeding cottonseed meal (a high-protein feed) with grazed turnips, gave a better milk yield response than grazed turnips alone.

Maize can be eaten as a green crop or made into silage. A problem with making maize silage in southern Victoria is the time required before the crop can be harvested (late April). It means pasture resowing is delayed. Maize also has a low protein content. This should be considered when balancing diets.

In northern Victoria, fodder crops such as sorghum and millet are grown. They make reasonable feeds while grazed, but if left to grow for silage, they are low in energy and protein.
Some forage crops can be toxic at certain stages of development. Therefore their grazing management should be discussed with local dairy officers and consultants.

In the past, oats were the only fodder crop normally grown as a winter feed, even though they are not well adapted to grazing. Now it is common practice to oversow paddocks with annual ryegrasses or to sow ryegrasses as a fodder crop because they are better adapted to grazing by cattle.

9.8 Energy and protein variation among feeds

The tables in this chapter highlight the wide variation in energy and protein levels among and within feeds. When formulating diets for dairy cows, estimates of the nutritive value of the diet are only as good as the information available on the ingredients. It is important to use reliable energy and protein values when formulating diets.
EXERCISE 9.1:

Use your knowledge of the nutritive value of feeds and minimum cow requirements to solve the following problems:

a) For each nutrient category, rank the feeds in boxes A–H from highest to lowest.

Write the identifying letter in the appropriate cell of the table.

b) Which feeds, on their own, would meet the minimum requirements of a 500 kg cow in early lactation, that is producing 25 L of milk with 4.2 per cent fat and 3.4 per cent protein?

Use Worksheet 1 to help you calculate the requirements of the cow.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late hay</td>
<td>Early silage</td>
<td>Turnips</td>
<td>Dairy pellets</td>
<td>Wet brewers grain</td>
<td>Good autumn pasture</td>
<td>Poor autumn pasture</td>
<td>Barley/lupin mix (20% lupin)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>DM (%)</th>
<th>Energy (MJ/kg DM)</th>
<th>Protein (% CP)</th>
<th>Fibre (% NDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 9.1b)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>A kg</td>
<td>For maintenance (Table 5.1)</td>
<td>I MJ</td>
</tr>
<tr>
<td>Daily activity level</td>
<td>B MJ/km</td>
<td>For activity</td>
<td>J MJ</td>
</tr>
<tr>
<td>Terrain: (1-5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MONTH OF PREGNANCY</td>
<td></td>
<td>For pregnancy (Table 5.2)</td>
<td>L MJ</td>
</tr>
<tr>
<td>D th month</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily milk production</td>
<td>E litres</td>
<td>For milk production (Table 5.3)</td>
<td>M MJ</td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat test</td>
<td>F %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein test</td>
<td>G %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>H kg/cow/day</td>
<td>For or from condition (Table 5.5)</td>
<td>N MJ</td>
</tr>
<tr>
<td>Gain + loss -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total daily needs of this cow:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>I + J + L + M ± N MJ</td>
<td>Crude protein</td>
<td>% from above</td>
</tr>
<tr>
<td>NDF fibre</td>
<td>% from above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10. **Effects of Supplements on Pasture Intake**

Supplements are usually intended to improve or maintain milk production, cow condition or pasture availability.

The impact of supplementary feeding can be difficult to assess because the results may not appear immediately in the vat.

In the short term, the response to a supplement may be small. But if the supplement is used to ‘carry the herd over’ to a period when availability of pasture improves or a lower-priced supplement (such as a crop) becomes available, then it may be important and ultimately profitable.

The factors affecting responses to supplementary feeding are numerous (Figure 10.1) and their interaction is complex. The results of supplementary feeding can vary.

![Figure 10.1: Some of the factors which influence the responses of dairy cows to supplementary feeding.](image)

The economic impact of supplements can only be assessed in relation to the overall farm feeding system. Nevertheless, it is the short-term or immediate response which impacts on cash flow.
10.1 Substitution

Grazing dairy cows may eat less pasture when supplements are fed. The term ‘substitution’ describes the extent to which a supplement replaces pasture which would otherwise have been eaten had the supplement not been offered.

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

Substitution rate is the reduction in pasture dry matter intake per kilogram of supplement offered. The major factor influencing substitution rate is the level of pasture intake achieved if no supplements had been fed.

A substitution rate of 0.25 means that for every kg DM of supplement eaten, pasture intake will fall by 0.25 kg DM.

Table 10.1 presents results from a series of short-term grazing trials conducted at the Ellinbank Dairy Research Institute in Gippsland.

Six herds in early lactation were rotationally grazed on spring pastures.

Three stocking rates were used: low, medium, and high. At each stocking rate, the diet of one herd was supplemented with 3.2 kg DM/cow/day of commercial pellets. The other herd was not fed supplements.

At the low stocking rate, the unsupplemented cows utilised less than 50 per cent of the available pasture.

The total dry matter intake of the supplemented cows on the low stocking rate increased by only 1.0 kg/day and milk yield by 0.9 litres/day. They consumed 0.69 kg less pasture for every kg of supplement fed. The milk response was less than 0.28 litres per kilogram of supplement fed.

At the medium and high stocking rates, milk responses rose to 0.69 L and 0.97 L, respectively. Substitution rate declined as stocking rate increased.
Table 10.1: The effect of stocking rate and supplement feeding on pasture intakes and milk yield in early lactation.

<table>
<thead>
<tr>
<th>Supplements (kg/cow/day)</th>
<th>Stocking rate (cows/ha)</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>3.2</td>
<td>0</td>
</tr>
<tr>
<td>Pasture Allocation (kg DM/cow/day)</td>
<td>33</td>
<td>33</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Pasture Intake (kg DM/cow/day)</td>
<td>15.9</td>
<td>13.7</td>
<td>11.8</td>
<td>11.0</td>
</tr>
<tr>
<td>Total Intake (kg DM/cow/day)</td>
<td>15.9</td>
<td>16.9</td>
<td>11.8</td>
<td>14.2</td>
</tr>
<tr>
<td>Substitution Rate (kg of pasture not eaten for each kg of supplement fed)</td>
<td>-</td>
<td>0.69</td>
<td>-</td>
<td>0.25</td>
</tr>
<tr>
<td>Milk Yield (litres/cow/day)</td>
<td>23.1</td>
<td>24.0</td>
<td>20.9</td>
<td>23.1</td>
</tr>
<tr>
<td>Milk Response to Supplement (litres milk/kg supplement fed)</td>
<td>-</td>
<td>0.28</td>
<td>-</td>
<td>0.69</td>
</tr>
</tbody>
</table>

(Source: Grainger and Matthews, 1989)

As stocking rate increases, substitution rate falls.
As stocking rate increases, milk response to supplementary feeding improves.

For cows to have high pasture DM intakes, they must be offered a lot more pasture than they can eat. Unfortunately, the utilisation of that pasture gets worse as farmers offer more pasture to their cows. This extra uneaten pasture will be wasted unless it is eaten at the next grazing, but by then some of it will have died and decayed while the remainder will be more mature and less palatable.

The extent to which substitution occurs depends on several factors:

*Amount of pasture allocated daily.*

*Intake limit of the cow.* The closer the cow is to the limit of her feed intake when a supplement is offered, the greater the substitution.
Quality of pasture. If the pasture is the same or poorer quality than the supplement, then the supplement will be eaten first.

Cows grazing abundant, high-quality pasture and fed high-quality supplements, will eat the supplement rather than the pasture. Almost complete substitution occurs (i.e. cows eat 1 kg less pasture for each 1 kg of supplement eaten).

Type of supplement. Substitution is generally greater when roughage (hay, silage) supplements are fed than when concentrates are fed. This reflects the volume the supplements occupy in the rumen and how quickly they are digested to make room for more feed (i.e. roughages are bulky and are digested slowly).

Balance of the diet as a result of feeding supplements. If the supplement corrects a dietary imbalance, less substitution occurs and intake may increase. However, if an imbalance is made worse, total intake may be reduced.

Where there is an ample supply of pasture, cows will usually reduce their intake of pasture by 0.3–0.9 kg DM for each kg DM of grain or pellets eaten. If the substitution rate is less than 1.0, it means that total DM intake increases when concentrates are fed.

Substitution is greatest (closest to 1.0, or 100 per cent) when plenty of highly digestible pasture is available and large amounts of concentrates are fed. Substitution is lowest (closest to 0) when little pasture is available and small amounts of concentrates are fed.

As the intake of energy increases, the amount of extra milk produced from each extra unit of energy decreases. In other words, the marginal, or additional, milk response decreases as the level of supplement intake increases.

The main reason for the decreasing marginal milk response is that, with successive increments of feed energy, the cow increasingly partitions nutrients from milk production to body tissue production as milk production approaches the cow’s genetic potential.

On farm, it is difficult to determine the precise amount of substitution that occurs. If pasture is of good quality and cows are leaving too much behind, you can be confident the substitution rate is at the higher end of the scale.
Remember, pasture left behind will be of low quality and palatability by next grazing, causing a lower amount of pasture to be eaten at this and future grazings.

**10.2 How cows respond to supplements**

Responses to supplementary feeding have both immediate and delayed components. Some of the supplement goes immediately to milk production and some goes to body fat, which contributes to milk production at a later stage when condition is ‘mobilised’.

To manage the feeding of supplements effectively, it is important to know how cows respond to them. The response is variable. It depends on the circumstances in which the supplement is fed.

The response in milk yield is generally due to the extra energy in the supplement. Unless the supplement improves the use of nutrients already in the diet, you will not get any more milk than the energy the supplement contains. As most supplements contain around 11 MJ/kg DM, there is only enough energy for a response of approximately 2 L of milk per kg DM of supplement.

In practice, pasture substitution almost always occurs, resulting in the response being less than that predicted from the amount of energy in the supplement. The response will reduce by the equivalent of the energy in the pasture no longer eaten. Also, some of the energy in the supplement goes to condition score rather than straight into milk. So the immediate milk response will be smaller again.

Most experiments have only measured the immediate response to supplements. In a review by Kellaway and Porter (1993), only two experiments reported results on immediate milk response and delayed milk response from condition score (ie. the total response).

One experiment found a total response of 1.1 L of milk per kg DM of supplement fed. The other reported a total response of 2.5 L of milk per kg DM of supplement fed.

We know more about the immediate response to supplements.
In early lactation, the average immediate response to concentrate feeding is 0.6 L of milk per kg of supplement (range: 0.2 to 1.0 L).

In mid-lactation to late lactation, the average immediate response is 0.5 L of milk per kg of supplement (range: 0.3 to 0.8 L).

More recent research from Ellinbank and Kyabram has measured immediate responses ranging between 0.1 and 1.6 L per kg of supplement.

A rule of thumb sometimes used is that ‘you get half the response now and half later when the condition score energy is converted to milk’. Given the scant experimental evidence, it is not possible to say whether this is true or not.

At this point, you may wonder what to make of the milk response to supplementary feeding.

When trying to estimate the response to a supplement, ask yourself, ‘Does the supplement meet a need of the cow?’ Her needs are for quantity and quality of feed.

10.2.1 Quantity of pasture

If the cow already has enough to eat, feeding more is unlikely to result in a big increase in milk production. However, a hungry cow should give a good response.

There seems to be a good relationship between the amount of pasture on offer and the size of the milk response to supplement. When the quantity of pasture offered is low, the response to feeding supplement is relatively large. High pasture allowance results in little or no response to supplement feeding. The difficulty is determining the availability of a particular pasture to the cow. For example, 30 kg of dry matter per cow is more available if it is provided as 12 cm high pasture rather than as a larger area of 3 cm high pasture.

The type of pasture left after grazing is a good guide to how hungry a cow is (and so is her preparedness to eat more). If the cow is prepared to eat pasture of low palatability, her preparedness to eat more is likely to be high. If she is being fussy about what pasture she eats and leaves good quality pasture uneaten, the cow is indicating she has enough to eat and is able to be choosy.
10.2.2 Quality of pasture

If the pasture quality is as good as the quality of the supplement that replaces it, you would expect little or no response (if quantity of pasture was not limiting intake).

If the pasture quality is low compared with the supplement quality, you would expect a relatively good response. This is due to the supplement containing more nutrients than the pasture it replaces and because feed of higher quality has a positive effect on intake.

10.3 When is supplementary feeding profitable?

The profitability of supplements is easiest to determine when feed intake is well below cow requirements. It will not only be a matter of profitability, but of survival. The animal needs to be fed to survive.

The next level is when cows are moderately well fed. A typical total milk response is about 0.5 L now and perhaps 0.5 L later for each kilogram DM of supplement. A simple look at profit and cost would suggest break-even is when the cost of the supplement is equal to the value of the total milk response.

**EXAMPLE 10.1:**

\[
\begin{array}{ccc}
22c/L & \times & 0.5 \text{ L/kg DM of sup. fed} \\
\text{(price now)} & & \text{(immediate response)} \\
& & = 11c
\end{array}
\]

\[
\begin{array}{ccc}
18c/L & \times & 0.5 \text{ L/kg DM of sup. fed} \\
\text{(price next lactation)} & & \text{(delayed response)} \\
& & = 9c
\end{array}
\]

Total benefit = 20c

In this case, it is profitable to feed the supplement if it costs less than 20c/kg DM.

A third situation is when cows are well fed at pasture but supplements are fed to increase milk yield. The total response from each kg DM of supplement fed will be closer to 0.25 L now and perhaps 0.25 L in the next lactation coming from condition.

The break-even point to make a profit from this can be estimated as before.
EXAMPLE 10.2:

<table>
<thead>
<tr>
<th></th>
<th>22c/L (price now)</th>
<th>0.25 L/kg DM of sup. fed (immediate response)</th>
<th>= 5.5c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18c/L (price next lactation)</td>
<td>0.25 L/kg DM of sup. fed (delayed response)</td>
<td>= 4.5c</td>
</tr>
</tbody>
</table>

Total benefit = 10c

The supplement would need to cost less than 10c/kg DM for supplementary feeding to be profitable.

However, there is more than just the effect on milk production to consider. For example:

- Without supplementary feeding the cows may lose too much body condition, which would affect their ability to get in calf.

- The cows may be grazing to below 3–4 cm. This slows pasture growth. A short period of supplementary feeding would benefit pasture growth and help feed the cows better pasture at the next grazing.

- Feeding supplements may enable a higher stocking rate, which could allow pasture to be better and more profitably utilised, even though at certain times of the year the supplements might not give an immediate profit.

10.3.1 Excessive use of supplements

Overuse of supplements reduces pasture quality and utilisation and depresses milk production at subsequent grazings.

You need to be the judge of how large or profitable the response will be based on the evidence.

A crude test to determine the size of the response is to put a kilogram of supplement into the diet, or take a kilogram out, and then watch what effect that has in the vat and on how much pasture remains after grazing.
11.  **Formulating a Diet**

Formulating a diet is an important part of an everyday feeding strategy. It is a means of meeting production and financial goals by feeding to the specific requirements of the cow in the most economical way.

To formulate a diet, we have to know the quantity of nutrients the cow or herd needs to meet production and animal health goals, and the nutrient content of the feeds.

A balanced diet is one in which:

\[
\text{cow nutrient requirements} = \text{nutrients available in the diet.}
\]

Another consideration in balancing diets is whether the cow is physically able to eat the amount of feed we intend to provide.

The final consideration is economics. The economic response from feeding specific nutrients must be more than their cost. This aspect is often forgotten.

Diet formulation is largely a set of mathematical procedures. However, close observation of cows is also important. Herd production, fertility, body condition and health are good indicators of nutritional imbalances.

### 11.1 Information needed to formulate a diet

#### 11.1.1 Cow requirements

Cow requirements should be calculated on realistic production goals. Factors to consider are milk production and composition, animal activity, weight, stage of pregnancy and changes in body condition.

Minerals and vitamins are necessary to fine tune the system. Often trace element deficiencies are regional and seasonal. Their variability may depend on pasture management. When the basal diet is predominantly pasture, most of these problems can be reduced by managing pastures well.
Minerals and vitamins have not been included in the exercises in this chapter, although it is important to know whether deficiencies are present on your farm.

11.1.2 Nutrients in feeds

Feeding of dairy cows in Victoria is predominantly pasture-based. Pasture is the cheapest feed available when it is fully utilised. The main aim of supplementary feeding is to use the pasture to its maximum, as well as filling feed gaps that occur due to seasonal and management variations.

In pasture-based systems, the most limiting nutrient for milk production is energy.

11.1.3 How to formulate a diet

The group of exercises in this chapter will introduce you to one way of calculating whether the diet of your cows is appropriate if they are to reach their expected lactation and liveweight performance.

As you fill in the worksheets, you will need to refer to previous chapters or to Appendix C, where all of the necessary tables are collated. You will need to use a calculator to complete this section. Answers to the exercises are given in Appendix A.
Exercise 11.1: Calculate the requirements of cows in this herd.

The farm is:
- on flat land, and
- the cows walk an average of 5 km per day to be milked.

The herd comprises:
- 160 Friesian dairy cows in early lactation with an average liveweight of 550 kg

The herd produces:
- 4000 litres per day
- Fat and protein tests are 4.6 per cent and 3.2 per cent respectively
- The cows are losing roughly 1.5 kg liveweight per day, or just over one condition score a month.

From this information, determine the nutritive requirements of the cows, using Worksheet 1.

Hints:

Cows are in early lactation. Therefore, there is no need to account for pregnancy.

Cows are losing condition. Fat is being mobilised to provide energy for milk production and other needs.
## Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 11.1)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>A kg</td>
<td>For maintenance (Table 5.1)</td>
<td>I MJ</td>
</tr>
<tr>
<td>Daily activity level</td>
<td>B</td>
<td>For activity</td>
<td>J MJ</td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td>MJ/km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td>D</td>
<td>for pregnancy (Table 5.2)</td>
<td>L MJ</td>
</tr>
<tr>
<td>Daily milk production</td>
<td>E</td>
<td>For milk production (Table 5.3)</td>
<td>M MJ</td>
</tr>
<tr>
<td>Volume</td>
<td>litres</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Fat test</td>
<td>%</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Protein test</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>H</td>
<td>For or from condition (Table 5.5)</td>
<td>N MJ</td>
</tr>
<tr>
<td>gain + loss -</td>
<td>kg/cow/day</td>
<td>from H</td>
<td>MJ/kg</td>
</tr>
<tr>
<td>Total daily needs of this cow:</td>
<td></td>
<td>Energy</td>
<td>I + J + L + M ± N MJ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crude protein from above</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NDF fibre from above</td>
<td>%</td>
</tr>
</tbody>
</table>

For a blank Worksheet, see Appendix F.
Exercise 11.2: Determine the nutritive value of the usual diet.

For most purposes, feed is talked about and measured in kilograms of dry matter (kg DM). However, we must often deal with ‘wet,’ or as-fed, weights.

This farm is pasture-based, with supplements of wheat and silage. Pasture is kept short and leafy most of the year and is of relatively good quality. The farmer has had analyses made of the feed used on the farm, and the results are given in Table 11.1.

Rotational grazing allows 1600 kg DM pasture to be consumed by the herd each day:

1600 kg DM ÷ 160 cows = 10 kg DM/cow
(Sample 1; Table 11.1)

Plenty of silage left from last year is also offered at 7 kg (as-fed)/cow/day (Sample 2; Table 11.1)

Wheat is readily available and offered at 5.6 kg (as-fed)/day (Sample 3; Table 11.1)

From this information, use Worksheet 2 to determine a cow’s total intake of energy, protein and fibre from this diet.
Table 11.1: Estimates of feed analyses.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>Reference</th>
<th>Sample Details</th>
<th>Moisture</th>
<th>Dry Matter</th>
<th>Crude Protein (of dry matter)</th>
<th>Neutral Detergent Fibre (of dry matter)</th>
<th>Digestibility (digestible dry matter)</th>
<th>Estimated Metabolisable Energy (ME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE 1</td>
<td>Short Feed</td>
<td>Pasture</td>
<td>82.6%</td>
<td>17.4%</td>
<td>25.8%</td>
<td>28.4%</td>
<td>77.8%</td>
<td>11.2 MJ/kg dry matter</td>
</tr>
<tr>
<td>SAMPLE 2</td>
<td>Silage</td>
<td>Pasture</td>
<td>71.2%</td>
<td>28.8%</td>
<td>12.1%</td>
<td>50.0%</td>
<td>59.5%</td>
<td>8.0 MJ/kg dry matter</td>
</tr>
<tr>
<td>SAMPLE 3</td>
<td>Grain</td>
<td>Wheat</td>
<td>10.2%</td>
<td>89.8%</td>
<td>12.6%</td>
<td>5.0%</td>
<td>86.4%</td>
<td>12.8 MJ/kg dry matter</td>
</tr>
<tr>
<td>SAMPLE 4</td>
<td>Rank Feed</td>
<td>Pasture</td>
<td>75.4%</td>
<td>24.6%</td>
<td>12.0%</td>
<td>56.1%</td>
<td>59.0%</td>
<td>8.0 MJ/kg dry matter</td>
</tr>
</tbody>
</table>
### Worksheet 2: The energy, protein and fibre content of a diet (Exercise 11.2)

<table>
<thead>
<tr>
<th></th>
<th>Pasture</th>
<th>Supplement 1:</th>
<th>Supplement 2:</th>
<th>Supplement 3:</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry matter</strong></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td>F</td>
<td>G</td>
<td>H</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td><strong>Fibre</strong></td>
<td>O</td>
<td>P</td>
<td>Q</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td><strong>Pasture</strong></td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
</tr>
<tr>
<td><strong>Supplement 1:</strong></td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
</tr>
<tr>
<td><strong>Supplement 2:</strong></td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
</tr>
<tr>
<td><strong>Supplement 3:</strong></td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
<td>Kg DM /cow/day</td>
</tr>
<tr>
<td><strong>Total daily dry matter intake</strong></td>
<td>A+B+C+D kg DM/cow</td>
<td>F+G+H+I MJ/cow</td>
<td>J+K+L+M kg/cow</td>
<td>J+K+L+M kg/cow</td>
<td></td>
</tr>
<tr>
<td><strong>Total daily DM intake limit</strong></td>
<td>Use T and Table 11.2 or the formula (120 ÷ T) ÷ 100 X liveweight kg/cow</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Cow requirements (from Worksheet 1)

- **Total daily energy requirement**
- **Crude protein requirement**
- **Fibre requirement**

**Chapter 11: Formulating a Diet**

For a blank Worksheet, see Appendix F.
Exercise 11.3: Revise the diet to account for pasture maturity.

As ryegrass and clover pastures mature, their quality deteriorates. What would happen if, instead of good quality pasture, the farmer was feeding longer, ranker pasture?

The same amounts of wheat and silage are offered as in Exercise 11.2.

Instead of good-quality pasture, the farmer now feeds poorer-quality pasture at 10 kg DM/cow/day.
(Sample 4; Table 11.1)

From this information, use Worksheet 2 to determine the total intake of energy, protein and fibre from this diet.
### Worksheet 2: The energy, protein and fibre content of a diet (Exercise 11.3)

<table>
<thead>
<tr>
<th>Dry matter</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td></td>
<td>10 X</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>28.8</td>
<td>2 X 8</td>
</tr>
<tr>
<td>C</td>
<td>5.6</td>
<td>89.8</td>
<td>5 X 12.8</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total daily dry matter intake**

A + B + C + D kg DM/cow/day

**Total daily energy intake**

F + G + H + I MJ/cow/day

**Total daily protein intake**

J + K + L + M kg/cow/day

**Total daily fibre intake**

O + P + Q + R kg/cow/day

**Cow requirements**

(from Worksheet 1)

**Total daily energy requirement**

MJ

**Crude protein requirement**

%

**Fibre requirement**

% NDF

**Protein % of ration**

N/E X 100

**NDF % of ration**

S/E X 100

**Use T and Table 11.2 or the formula**

(120 ÷ T) X live weight kg/cow
After completing the previous three exercises, consider the following question in Exercise 11.4.

**Exercise 11.4: Do the diets meet cows’ requirements?**

Comparing Worksheet 1 with the two versions of Worksheet 2 to determine whether the diets meet the cows’ energy, protein, and fibre requirements.

Summarise the information in the table:

<table>
<thead>
<tr>
<th>Situation</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows’ requirements (Exercise 11.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usual diet (Exercise 11.2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorer-pasture diet (Exercise 11.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 11.2 Estimating the limits of feed intake

As well as knowing what the cow needs and what nutrients the feeds can provide her, we also need to be sure that the cow can eat the amount of food which can provide those nutrients. This section contains two rules of thumb for estimating how much cows will eat. These tests can be used when deciding how much to offer your cows or for feed planning.

How much could a cow eat, given a particular feeding situation?

We would be pretty clever if we could accurately predict intake limits. However, we need to start somewhere.

It is difficult to measure intake of grazing animals accurately. However, as pasture managers, we need this information to get the best from pastures.

#### 11.2.1 Cow size and feed quality

Cow size and feed quality are two major influences on feed intake. It comes as no surprise that rules of thumb for estimating cow intake limits are based on these two factors.

Other things also affect intake, so remember that there will be exceptions to these rules.
One rule of thumb is that a cow can generally eat 3 per cent to 4 per cent of her bodyweight.

**Example 11.1: Estimating the intake limits of cows of various weights, using 3 per cent of their bodyweight.**

- $475 \text{ kg} \times (3 \div 100) = 14.3 \text{ kg DM/day intake limit.}$
- $500 \text{ kg} \times (3 \div 100) = 15 \text{ kg DM/day intake limit.}$
- $550 \text{ kg} \times (3 \div 100) = 16.5 \text{ kg DM/day intake limit.}$

**Example 11.2: Estimating the intake limits of cows of various weights, using 4 per cent of their bodyweight.**

- $475 \text{ kg} \times (4 \div 100) = 19 \text{ kg DM/day intake limit.}$
- $500 \text{ kg} \times (4 \div 100) = 20 \text{ kg DM/day intake limit.}$
- $550 \text{ kg} \times (4 \div 100) = 22 \text{ kg DM/day intake limit.}$

Cow size on its own may not be a good indicator of intake limits for individual cows. Cows of the same weight can differ in appetite, in rumen capacity or in grazing habits.

Feed of the same quality may be eaten in different amounts, depending on how long it is, or how palatable the cow thinks it is.

Some American and European advisers on dairy nutrition use another rule of thumb:

As the percentage of neutral detergent fibre (NDF) increases in forages, cows eat less according to the following formula:

$\frac{(120 \div \text{NDF})}{100} \times \text{liveweight} = \text{kg DM/d maximum intake}$

**Example 11.3: Estimating the intake limits of cows of various weights eating a feed of 35 per cent NDF.**

- $(120 \div 35) \div 100 \times 475 \text{ kg} = 16.3 \text{ kg DM/day intake limit.}$
- $(120 \div 35) \div 100 \times 500 \text{ kg} = 17.1 \text{ kg DM/day intake limit.}$
- $(120 \div 35) \div 100 \times 550 \text{ kg} = 18.9 \text{ kg DM/day intake limit.}$
Table 11.2 lists the maximum daily intake of cows using various NDF percentages.

Table 11.2: Maximum daily intake of cows as affected by the NDF per cent of the diet.

<table>
<thead>
<tr>
<th>Live-weight (kg)</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4.8</td>
<td>4.0</td>
<td>3.4</td>
<td>3.0</td>
<td>2.7</td>
<td>2.4</td>
<td>2.2</td>
<td>2.0</td>
<td>1.8</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>150</td>
<td>7.2</td>
<td>6.0</td>
<td>5.1</td>
<td>4.5</td>
<td>4.0</td>
<td>3.6</td>
<td>3.3</td>
<td>3.0</td>
<td>2.8</td>
<td>2.6</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>200</td>
<td>9.6</td>
<td>8.0</td>
<td>6.9</td>
<td>6.0</td>
<td>5.3</td>
<td>4.8</td>
<td>4.4</td>
<td>4.0</td>
<td>3.7</td>
<td>3.4</td>
<td>3.2</td>
<td>3.0</td>
</tr>
<tr>
<td>250</td>
<td>12.0</td>
<td>10.0</td>
<td>8.6</td>
<td>7.5</td>
<td>6.7</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.6</td>
<td>4.3</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>300</td>
<td>14.4</td>
<td>12.0</td>
<td>10.3</td>
<td>9.0</td>
<td>8.0</td>
<td>7.2</td>
<td>6.5</td>
<td>6.0</td>
<td>5.5</td>
<td>5.1</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>350</td>
<td>16.8</td>
<td>14.0</td>
<td>12.0</td>
<td>10.5</td>
<td>9.3</td>
<td>8.4</td>
<td>7.6</td>
<td>7.0</td>
<td>6.5</td>
<td>6.0</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td>400</td>
<td>19.2</td>
<td>16.0</td>
<td>13.7</td>
<td>12.0</td>
<td>10.7</td>
<td>9.6</td>
<td>8.7</td>
<td>8.0</td>
<td>7.4</td>
<td>6.9</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>450</td>
<td>21.6</td>
<td>18.0</td>
<td>15.4</td>
<td>13.5</td>
<td>12.0</td>
<td>10.8</td>
<td>9.8</td>
<td>9.0</td>
<td>8.3</td>
<td>7.7</td>
<td>7.2</td>
<td>6.8</td>
</tr>
<tr>
<td>500</td>
<td>24.0</td>
<td>20.0</td>
<td>17.1</td>
<td>15.0</td>
<td>13.3</td>
<td>12.0</td>
<td>10.9</td>
<td>10.0</td>
<td>9.2</td>
<td>8.6</td>
<td>8.0</td>
<td>7.5</td>
</tr>
<tr>
<td>550</td>
<td>26.4</td>
<td>22.0</td>
<td>18.9</td>
<td>16.5</td>
<td>14.7</td>
<td>13.2</td>
<td>12.0</td>
<td>11.0</td>
<td>10.2</td>
<td>9.4</td>
<td>8.8</td>
<td>8.3</td>
</tr>
<tr>
<td>600</td>
<td>28.8</td>
<td>24.0</td>
<td>20.6</td>
<td>18.0</td>
<td>16.0</td>
<td>14.4</td>
<td>13.1</td>
<td>12.0</td>
<td>11.1</td>
<td>10.3</td>
<td>9.6</td>
<td>9.0</td>
</tr>
<tr>
<td>650</td>
<td>31.2</td>
<td>26.0</td>
<td>22.3</td>
<td>19.5</td>
<td>17.3</td>
<td>15.6</td>
<td>14.2</td>
<td>13.0</td>
<td>12.0</td>
<td>11.1</td>
<td>10.4</td>
<td>9.8</td>
</tr>
</tbody>
</table>

(Source: Linn and Martin, 1989.)

If cows can select within their diets, allowance should probably be made for less fibre in the diet. For example, if the diet on offer tests at 40 per cent NDF, then the actual selected diet may be 5 per cent to 10 per cent lower (i.e. 38 per cent to 36 per cent NDF).

This rule applies to empty cows. The capacity of pregnant cows is less because the rumen size is reduced by the increased size of the womb.

Exercise 11.5: Can cows physically eat that much feed?

Calculate the cows’ intake limit, using the NDF percentages from Exercises 11.1, 11.2, 11.3 and either Table 11.2 or the formula relating intake to NDF. Use the table below to compare these limits with the intakes calculated earlier.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Total daily DM intake (kg DM)</th>
<th>Daily DM intake limit (kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual (Exercise 11.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poorer pasture (Exercise 11.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COMMENTS ON EXERCISES 11.1 – 11.5

- Good quality pasture with supplements meets the requirements of the cow. The fibre is lower than 30 per cent NDF and therefore may be too low; however, intake in early lactation may be limited by gut fill. Lower fibre diets fed during this time may ensure greater intakes of energy, but this value will need to be adjusted as animal intake increases through lactation.

- Poor quality pasture may lead to deficiencies and production losses. The poor quality diet is deficient in energy and protein. It requires more energy and protein. More poor quality pasture must be fed to equal the energy intake from good quality pastures. However, the fibre content of the pasture is high and may limit intake.

11.3 To balance a diet

To balance a diet, you need to know what the nutrient deficiencies are. For example, in Exercise 11.3, energy and protein were lacking. This diet can be balanced by offering more pasture or by including more supplements to increase energy and protein levels in the diet. This is very much trial and error.

Available pasture from a specific rotation determines the level of pasture in the diet, and supplements add to this base. There are generally a number of diet formulations that can meet the requirements of the cow.

11.4 Costs of supplements

Choosing the most economical supplement depends on the deficiency being corrected: whether energy, protein or fibre.

For example, if energy is deficient, then choose the feed that provides the most energy at the cheapest price per megajoule.

Price per tonne of DM can be deceptive. Look at the composition of the dry matter. Prices for wet or as-fed feed are even more deceptive: who wants to pay for water?
11.4.1 Things to remember when buying or producing a feed:

- Nutrient content: energy, protein, fibre
- Cost per unit of nutrient: MJ, protein, fibre
- Cost per kg DM.

**Exercise 11.6: Calculate cost of the nutrients in the following feeds.**

**Assume that:**
- **Silage is $41 per round bale (weighing 460 kg wet weight).**
- **Wheat is $250/tonne wet.**

Use Worksheet 3 to calculate the cost of energy and protein in round bale silage and wheat.

**Silage**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture</strong></td>
<td>71.2%</td>
</tr>
<tr>
<td><strong>Dry matter</strong></td>
<td>28.8%</td>
</tr>
<tr>
<td><strong>Crude protein</strong></td>
<td>12.1% DM</td>
</tr>
<tr>
<td><strong>Neutral detergent fibre</strong></td>
<td>50.0% DM</td>
</tr>
<tr>
<td><strong>Digestibility</strong></td>
<td>59.5% digestible DM</td>
</tr>
<tr>
<td><strong>Estimated ME</strong></td>
<td>8.0 MJ/kg DM</td>
</tr>
</tbody>
</table>

**Wheat**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture</strong></td>
<td>10.2%</td>
</tr>
<tr>
<td><strong>Dry matter</strong></td>
<td>89.8%</td>
</tr>
<tr>
<td><strong>Crude protein</strong></td>
<td>12.6% DM</td>
</tr>
<tr>
<td><strong>Neutral detergent fibre</strong></td>
<td>5.0% DM</td>
</tr>
<tr>
<td><strong>Digestibility</strong></td>
<td>86.4% digestible DM</td>
</tr>
<tr>
<td><strong>Estimated ME</strong></td>
<td>12.8 MJ/kg DM</td>
</tr>
</tbody>
</table>
Worksheet 3: The cost of nutrients in feeds
(Exercise 11.6)

### Feed 1:

|                  |  
|------------------|------------------|
| **Cost per kg DM** | $\frac{X \div 100}{\text{DM \%}}$  
| **kg bought (i)** | **kg DM bought**  
| **DM \%**        | **B**  
| **Cost of (i) ($)** | $\times 100^{\dagger}$  
| **kg DM bought** | **c/kg DM**  
| **B**            | **C**  
| **Cost per MJ ME** | $\frac{100}{\text{MJ ME} \div \text{kg DM}}$  
| **c/kg DM (from B)** | **c/MJ ME**  
| **MJ ME \div \text{kg DM}** | **D**  
| **Cost per kilogram crude protein (or NDF)** | $\frac{100}{\text{CP \% (or NDF \%)} \div \text{c/kg DM (or c/kg NDF) \times 100}}$  
| **c/kg DM (from B)** | **c/kg CP (or c/kg NDF)**  
| **CP \% (or NDF \%)** | **D**  

### Feed 2:

|                  |  
|------------------|------------------|
| **Cost per kg DM** | $\frac{X \div 100}{\text{DM \%}}$  
| **kg bought (i)** | **kg DM bought**  
| **DM \%**        | **B**  
| **Cost of (i) ($)** | $\times 100^{\dagger}$  
| **kg DM bought** | **c/kg DM**  
| **B**            | **C**  
| **Cost per MJ ME** | $\frac{100}{\text{MJ ME} \div \text{kg DM}}$  
| **c/kg DM (from B)** | **c/MJ ME**  
| **MJ ME \div \text{kg DM}** | **D**  
| **Cost per kilogram crude protein (or NDF)** | $\frac{100}{\text{CP \% (or NDF \%)} \div \text{c/kg DM (or c/kg NDF) \times 100}}$  
| **c/kg DM (from B)** | **c/kg CP (or c/kg NDF)**  
| **CP \% (or NDF \%)** | **D**  

$^{\dagger}$To convert dollars per kilogram to cents per kilogram.
In this exercise, the price you pay for energy is essentially the same for wheat and silage. However, silage is cheaper if you require protein to balance the diet. Price comparisons will vary greatly with quality and price movements. Unfortunately, foodstuffs like silage are rarely bought on the basis of price for quality. As silage quality varies so much, so too will the price per megajoule.

11.4.2 Other considerations when costing supplements

Decisions on what supplements to feed depend on more than just the cost of the feed itself. Increased capital requirements, extra labour and other costs need to be considered when deciding on the supplement to best balance a diet.

For example, feeding brewers grain requires storage facilities, a front-end loader and maybe a feed-out cart, and a feed trough or feed pad. Farmers often select commercial pellets as their initial supplement because they are generally more consistent in quality than cereal grains and do not require any processing. Lupins are becoming popular as sources 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 supplement to cereal grains and commercial pellets. Once farmers have invested in equipment to handle by-products, the range of supplements that can be fed increases. The best and most economical feed will vary from farm to farm given the farmer’s situation and equipment.

11.5 Consequences of unbalanced diets

Some indicators of unbalanced diets can be used to identify dietary problems.

11.5.1 Rumination

After an initial grazing period animals normally start to ruminate or chew their cud.

If this is not occurring in a large percentage of the herd, then there may be a lack of fibre in the diet. This may be confirmed by looking for changes in milk composition (see Section 11.5.3).
11.5.2 Loose manure

If faecal material is very loose and watery it may indicate a lack of fibre in the diet.

This can also be checked by assessing any changes in milk composition.

11.5.3 Low fat test

A drop in fat test tends to occur when the herd is placed on a low fibre diet (e.g. a diet high in cereal grain and lush pasture).

When fibre is fermented by the rumen microbes, the resulting end product, acetate, is used to produce milk fat. If the level of fibre in the diet is low, milk fat production decreases.

The easiest way to increase the fibre content of the diet is to feed hay. Take care though when feeding out poor quality hay. A drop in dietary energy intake could cause milk and protein yield to fall.

11.5.4 Low protein test

Low milk protein content is common in early lactation when the cow is in negative energy balance. In other words, her energy needs are greater than her intake and she is losing body condition.

A shortage of energy reduces protein utilisation by rumen microbes. As a result, the supply of microbial protein, the cow’s major protein source, is reduced.

Under most circumstances, providing a higher energy diet will lift protein test.

A cow will only respond to protein supplementation with a lift in protein test if she is truly deficient in dietary protein. This is because she is unable to utilise energy properly when there is a protein shortfall.

When protein is lacking, microbial growth is depressed. As a result, microbial fermentation is reduced and less energy becomes available to the cow. She loses weight to compensate for the lack of dietary energy.

When fat is mobilised, milk fat test tends to go up.
**11.6 Metabolic disorders and unbalanced diets**

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.

Metabolic disorders such as ketosis and acidosis are usually linked to low intakes around calving or to abrupt changes in diet.

Managing nutrition well during the dry period and in early lactation is the key to preventing or minimising the occurrence of metabolic disorders.

The aim is to:

- Maximise nutrient intake around calving and in early lactation by providing enough high quality feed
- Avoid decreases in intake caused by sudden changes in diet when cows calve and join the milking herd.

Nutritional management at this time also plays a major role in minimising milk fever and grass tetany.

**11.6.1 Milk fever**

Milk fever is caused by a sudden and severe decrease in blood calcium levels at the onset of lactation, due to large increases in demand for calcium for milk production.

The incidence of milk fever increases with age and the number of previous calves.

The cow has mechanisms for adapting to these increased demands for calcium.

The mechanisms are:

- increasing the absorption of calcium from the intestine
- 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 after the cow calves.

When this process does not happen quickly enough, calcium replenishment into the bloodstream cannot keep pace with the output of calcium in milk.
Once calcium levels fall, muscular tremors and paralysis occur, followed by cow collapse and eventually death.

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 she is ‘primed’ to meet the increased calcium demands after she calves.

Management strategies which can be implemented are:

*Feeding diets low in calcium during the dry period.*
In practice, this means restricting fresh pasture and providing grass-based hay instead.

*Altering the cow’s dietary cation-anion balance (DCAB).*
Cations are positively charged ions such as potassium and sodium. Anions are negatively charged ions such as chloride and sulfate.

**DCAB – dietary cation-anion balance**

DCAB refers to the balance between positive ions (sodium and potassium) and negative ions (chloride and sulphate). Ideally, negatives should outweigh positives, but this is difficult to achieve in a pasture-based system.

Feeding higher levels of negatively charged ions produces a condition called metabolic acidosis. It appears that cows can remove calcium from bone more rapidly when they are affected by metabolic acidosis. The calcium-mobilisation process is encouraged, thus preparing the cow for the increased requirements around calving.

To do this, the diet must be higher in anions than cations.

This means feeding lower levels of potassium and sodium.

**How can dietary cation-anion balance be managed?**

*Choose forages carefully.* They can affect the acid-base balance. Some forages are high in potassium (often due to potassium fertilisers).

Hays grown on soils with poor fertiliser histories generally contain less potassium.

*Feed anionic salts (also called acid salts).* These salts include magnesium sulphate (Epsom salts), ammonium sulphate
and ammonium chloride. Some of these salts are unpalatable. There are various methods of feeding them, including commercially prepared pelleted supplements. Note that mixing these salts into molasses to improve palatability is not a good idea, as molasses contains potassium, which, being positively charged, tends to cancel out the effect of feeding the extra negatively charged ions.

Anionic salt mixtures should be discontinued after calving.

11.6.2 Grass tetany

Grass tetany or grass staggers often occurs in lactating cows within the first few months after calving. It appears as muscular spasms and convulsions and can eventually cause death.

Grass tetany is associated with low magnesium levels in the blood. Since magnesium is not stored in the body, the cow relies on a daily intake of magnesium to meet her needs.

Conditions which reduce magnesium intake or blood magnesium levels include:

- Grass-dominant pastures which may not supply the magnesium necessary to meet the needs of a cow in early lactation
- Topdressing with potash (potassium) or nitrogenous fertilisers. These reduce the availability of magnesium to the animal (potassium and ammonia restrict the absorption of magnesium)
- Short periods of fasting which can occur during yarding, transport or exposure to cold, wet, windy weather.

Grass tetany can be prevented by including a magnesium supplement in the diet to provide each cow with 10–15 g of magnesium per day. Supplementation should begin one week prior to calving and end when clover content in pastures begins to improve. Common sources of magnesium are:

- Insoluble magnesium oxide (e.g. Causmag) dusted on to hay or added to bale feed at a rate of 50 g/cow/day or dusted on to pasture at a rate of 50–75 g/cow/day
• Magnesium incorporated into licks
• Soluble magnesium sulphate (Epsom salts) at a rate of 5 g/L/cow/day in drinking water or at a rate of 60 g/cow/day in a drench
• Soluble magnesium chloride at a rate of 5 g/litre/cow/day in drinking water or at a rate of 100 g/cow/day in a drench.

NOTE: High levels (over 30 g per cow per day) of granulated causmag (magnesium oxide) have been identified as a common factor in herds which are affected by severe outbreaks of Salmonella. This needs to be weighed up against the risk of grass tetany. Some veterinarians suggest lowering granulated causmag levels if a Salmonella case occurs.

11.6.3 Ketosis, or acetonaemia

Ketosis, or acetonaemia, occurs when the cow relies heavily on fat reserves for energy during early lactation. It is most common in cows fed low energy diets during early lactation.

When there is insufficient energy in the diet, the cow draws on body condition to make up the deficit.

Fat reserves contain ketones, a source of energy. Ketones are often used by the cow to supplement dietary energy, particularly during early lactation – hence the expression ‘milking off her back’. To prevent ketosis, feed a well balanced diet with enough energy to minimise the reliance on body fat reserves in early lactation. Supplying starchy feeds rich in rapidly fermentable carbohydrates (cereal grains) or feeding molasses can reduce the incidence of ketosis.

Ketosis highlights the need to avoid abrupt changes in the diet which may decrease intake in early lactation, and also underlines the importance of maximising nutrient intake with high quality feed during this period.

11.6.4 Lactic acidosis

Under extreme conditions, such as grain overload, large amounts of lactic acid are formed in the rumen. Acid may be produced faster than it can be absorbed or buffered. When lactic acid continues to build up, the rumen pH decreases (becomes more acidic) and microbial activity slows down. When the microbes stop working, fibre
digestion is reduced and voluntary food intake is depressed.

To avoid acidosis, grain should be introduced gradually (i.e., 0.5 kg grain or pellets/cow/day) so that the population of rumen microbes can adjust according to the type of fermentation that is required (more starch fermenting microbes may be needed). Remember, though, that different cows respond differently to grain feeding. Some cows can handle 6 kg of grain per day while others will get sick on 3 kg per day – and there is always a cow that will eat more than her share. The key to success is to make it a gradual daily increase and to watch your cows and check for symptoms of acidosis or grain poisoning.

Buffers can be in the diet to stabilise rumen pH so that the rumen environment allows a healthy population of rumen microbes.

11.7 Buffers

Buffers stabilise rumen pH and help prevent reductions in pH caused by acids produced in the rumen.

Saliva contains sodium bicarbonate and sodium biphosphate, which are both naturally occurring buffers. They neutralise rumen pH, keeping it stable at around 6 to 7.

When a cow chews her cud (especially in response to fibrous pasture plants) she produces large quantities of saliva (100–150 litres of saliva/cow/day).

If there is enough fibre in the diet, saliva production alone can generally maintain rumen pH. When cows are fed high levels of cereal grains, starch is fermented quickly in the rumen to produce volatile fatty acids (VFAs). The production of VFAs, especially lactic acid, may be greater than the rate at which they are absorbed or buffered. The resulting decrease in the pH of the rumen (increased acidity) stops other bacteria from digesting fibre. This in turn slows digestion and causes a loss of appetite.

The condition is commonly known as lactic acidosis. Oats are the safest grain to feed to avoid acidosis. Oats usually have a fibrous husk which causes the cow to salivate more during eating. In addition to this, more of the starch in oats is digested in the small intestine than the rumen so the
fermentation is slower compared with other grains. Note, however, that the quality of oats in terms of energy and protein content can be highly variable.

Fine milling or crushing of grain increases the digestibility of feed and the availability of energy in the rumen. However, milling may increase the incidence of acidosis. Rolling or cracking are recommended as alternatives.

Acidosis can be prevented in diets high in grain and low in roughage or fibre by supplying mineral buffers. Table 11.3 outlines some common buffers and additives used in high grain diets. However, these are not a substitute for fibre, and the fibre content of the diet must be maintained.

Table 11.3: Buffers and additives used in high grain diets.

<table>
<thead>
<tr>
<th>Additive/Buffer</th>
<th>% of diet DM</th>
<th>kg/t of grain</th>
<th>$/t of feed</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Bicarbonate (NaHCO₃)</td>
<td>1.5–2</td>
<td>15–20</td>
<td>9–13</td>
<td>Neutralises rumen acids to help prevent digestive upsets. Can be bitter and become unpalatable to stock if more than 4% fed. Tends to absorb moisture and form clumps which should be sieved out before feeding.</td>
</tr>
<tr>
<td>Causmag</td>
<td>Up to 1</td>
<td>10</td>
<td>6.50</td>
<td>Neutralises rumen acids. Source of magnesium to prevent grass tetany.</td>
</tr>
<tr>
<td>Sodium Bentonite</td>
<td>Up to 4</td>
<td>Up to 40</td>
<td>5–8</td>
<td>Found in most dairy pellets. Effectiveness as a buffer uncertain. Moderates the digestion of grains in the rumen and prevents cows from eating too much grain.</td>
</tr>
<tr>
<td>Crushed Limestone</td>
<td>1.5</td>
<td>15</td>
<td>1.20–1.50</td>
<td>Effectiveness as a buffer uncertain. Useful in high grain diets as a source of calcium &amp; magnesium.</td>
</tr>
</tbody>
</table>

11.8 Other feed additives

A feed additive can be described as a feed ingredient that produces a desirable animal response.

Feed additives have gained attention and use in recent years. Expected responses from feed additives include higher milk yields, increases in milk components, improved dry matter intake, a more stable rumen pH and improved fibre digestion. The primary feed additives currently being used are ionophores and antibiotics.
Rumensin® and Eskalin® are two commonly used additives which produce their effects by modifying the rumen environment. They alter the microbial population of the rumen, which in turn changes the mix of end products from microbial fermentation.

Rumensin® reduces the population of microbes that produce methane gas (which cannot be used by the cow as an energy source). The proportion of microbes that ferment feed to other more useful sources of energy is increased, resulting in improved milk yields. Responses to this additive depend on the diet and the stage of lactation.

Eskalin® inhibits the microbes that produce lactic acid and can therefore play a role in preventing lactic acidosis.
12. **Diet and its Effect on Milk Production and Body Condition**

A cow’s ability to produce milk depends largely on:

- Feed eaten; her intake of protein, energy and fibre. The feed must first be digested (broken down to its constituent parts) and the products of digestion absorbed into the blood from the digestive tract.

- How she uses (or partitions) the products of digestion for maintenance, activity, pregnancy, milk production or body condition.

This chapter deals mainly with how a cow partitions between milk, body condition and maintenance.

A cow’s intake (quantity and type of feed and the resultant products of digestion) and her use or partitioning of these products to metabolic activities all have an effect on the quantity (litres) and type (test) of milk she produces.

### 12.1 Products of digestion

There are a range of products from the digestion of feeds consumed by the dairy cow.

These include ammonia, carbon dioxide, methane, volatile fatty acids, fats, undigested fibre, rumen microbes and undegradable protein.

Some products of digestion are wasted (carbon dioxide, methane, undigested fibre), and some are used by the cow (see chapter 4).

### 12.2 Fate of the products of digestion

Fats (from acetate and fats in the diet), glucose (from propionate), and amino acids (from microbes and undegradable dietary protein), circulate in the cow's blood stream ready for their role in metabolic processes (**Figure 12.1**).
12.3 Milk production in the udder

12.3.1 What is milk?

Milk is produced by udder tissue. About 500 litres of blood pass through the udder to produce one litre of milk. Blood delivers water, glucose, fats and amino acids to the udder. Cells in the udder tissue use these substances to form and secrete milk:

*Water* in the milk comes from water in the blood.

*Lactose* (milk sugar) is produced from the glucose (from propionate) in the blood.

*Milkfat* comes from the fats (from acetate, fats in the diet, and released body fat) in the blood.
Chapter 12. Diet and Its Effect on Milk Production and Body Condition

Milk protein (mostly casein) is built from the amino acids (from microbes and undegradable rumen protein (UDP)) in the blood (using glucose as an energy source to do the building).

The level of fat and protein in milk varies, depending on the breed of cow, stage of lactation, and the diet. It follows, then, that the dollar value of milk varies too.

12.3.2 Lactose production in the udder

The udder makes lactose from glucose arriving in the blood. The lactose secreted into the udder attracts water with it, at roughly constant proportions. Therefore, the lactose content of milk does not change much. It usually stays at about 4.8 per cent.

Thus the quantity of glucose arriving at the udder determines how much lactose is produced and what volume of milk is produced.

<table>
<thead>
<tr>
<th>More blood glucose</th>
<th>More lactose (kg)</th>
<th>More milk (L)</th>
<th>Constant lactose test</th>
</tr>
</thead>
</table>

12.3.3 Milkfat production in the udder

The udder makes milkfat from fats carried in the blood.

The blood fats come from acetate (mainly from fibre in the diet), from the fat from body condition, or from fats in the diet (usually not a significant source).

Fat test (percentage) varies greatly, depending on:

- The type of energy in the diet. Fat test is higher when the diet is high in fibre. This is because the blood will carry more acetate, which is used for milkfat.

  However, fat test will be lower if the diet is high in starch. This is because the blood will contain more glucose (from the propionate), which is used for lactose production.

  On a high starch diet, not only is less milkfat produced, but the extra lactose produced increases the milk volume, diluting the fat even more

- The stage of lactation. Fat test is likely to be lower in early lactation when milk volume is at its highest
• Body condition of the cow. Fat test will be higher if the cow is losing body condition and using it for milkfat production. Body condition loss in early lactation (if the cow has condition to take off) may help maintain milkfat concentration as yield increases.

• Energy intake. Fat test tends to be lower if the cow is well fed. When her energy intake is high, the rumen fermentation rate is also high, the rumen is more acidic (lower pH), and the starch-digesting microbes which produce propionate will work better than the fibre-digesting microbes which produce acetate.

With more propionate (which is converted to glucose), there will be more lactose produced and, therefore, a greater volume of milk. With less acetate, there will be less fat.

12.3.4 Protein production in the udder

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.

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 feed because it wastes the protein-producing potential of the amino acids.

Conversely, if glucose is plentiful but amino acids are in short supply, the building of milk protein will be limited.

The surplus glucose may produce some lactose, but most will be stored; that is, the cow will put on body condition rather than produce milk. This also is not an efficient use of feed.

Milk protein and lactose production (and therefore milk volume) are related because:

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

(Remember, a diet higher in energy often produces more rumen microbes, which are digested to amino acids; and a high-energy diet also produces more propionate, which converts to glucose. On the other hand, a diet higher in fibre often produces less microbes and more acetate, which converts to fats.)

Amino acids can be broken down to glucose if there is a shortage of glucose. The reverse cannot occur.

Usually when milk protein production is high, lactose production is also high. Because lactose is high, milk volume is also high. So, as more kilograms of protein are produced, number of litres increases, keeping the protein test fairly constant. Therefore, the diet does not affect the protein percentage much, and certainly not as much as the diet affects fat percentage.

12.4 Milk production and body condition

Cow body condition (or the amount of fat that a cow has stored on her body), particularly at calving, has a large effect on milk production and fertility.

The cow either stores body fat or mobilises it, depending on the level and type of feed and the stage of lactation (Figure 12.2).
Chapter 12. Diet and its Effect on Milk Production and 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 is less than peak.
Body condition low but steady.

Late lactation:
Intake goes to body condition and milk.
Milk decreasing.
Condition increasing.

(Source: F. Tyndall, pers. comm.)

Figure 12.2: Changes in partitioning of nutrients over a lactation period.
Two hormones, which circulate in the cow’s blood, cause body fat to be used or stored:

*Insulin* regulates the storage of body fat from the fats and glucose in the blood. Insulin is produced by the pancreas and is in higher concentrations in the blood when cows are being fed well and glucose is plentiful in the blood.

*Growth hormone* regulates the release of body fat to produce milkfat. Growth hormone is produced by the pituitary gland and is in the blood in higher concentrations in early lactation or when cows are not fed well.

### 12.4.1 Body condition in early lactation

The ideal body condition score at calving is between 5 and 6. If the cow is fat enough at calving, it is common for one condition score to be taken off the body and used for milk production in the first two months of lactation. This is an important source of energy at a time when the cow is trying to achieve peak milk production and her appetite has not yet reached 100 per cent.

One condition score lost in early lactation produces about 220 litres of milk, about 10 kg of fat, and about 6.5 kg of protein, over the whole lactation.

If a cow is low in body condition at calving and is underfed in early lactation, her peak milk production will be depressed; and she will usually partition less feed to milk and more to body condition over the whole lactation.

Substances called ‘ketone bodies’ are produced as body fat is used. If body condition is being used rapidly, the high level of ketone bodies causes the metabolic disorder called acetonaemia (or ketosis). Milk production drops suddenly, cows become lethargic and may go down. Ketosis is caused by a low intake of energy relative to the requirement for milk production.

Ketosis can be prevented by increasing the cow's energy intake.

A cow in better condition at calving has better fertility. For each additional condition score at calving, the time between calving and first heat is reduced by 5–6 days.
12.4.2 Body condition in late lactation and in the dry period

Milk production falls in late lactation because:

- The cow is using (partitioning) more of her intake to build body condition rather than to produce milk.
- Her intake ability has decreased.
- Often, she is being offered less feed or lower quality feed.

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.

The dry period may be the only opportunity for cows to put on condition. Bear in mind though that cows use feed energy more efficiently to put on body condition while still milking (75 per cent efficient) compared to when dry (59 per cent efficient).

12.4.3 Summary of milk production and body condition

Cows must calve between condition scores 5 and 6 to ensure they have enough body fat to use in early lactation while feed intake lags behind milk production.

Adequate body reserves enables a high production peak to be achieved, which contributes to high milk production for the whole lactation.

Cows need to be well fed throughout the lactation to get body condition back on. They are more efficient at putting on body condition while still milking.

Exercises 12.1 and 12.2 assess your understanding of the production trends for given changes to a cow’s diet.
**EXERCISE 12.1: How do milk production and body condition change when diet changes?**

In all scenarios, the cows have access to plenty of good-quality pasture (24 per cent protein, 30 per cent NDF). In the following table, some changes that could be made to their diet are shown. Describe how a cow’s milk production (litres, fat test, protein test) and body condition might change, if her diet is changed. (Answer Up, Down or Steady)

<table>
<thead>
<tr>
<th>Diet change</th>
<th>Up, Down or Steady?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milk (L)</td>
</tr>
<tr>
<td>Wheat fed gradually increases from 1 kg to 4 kg per cow.</td>
<td></td>
</tr>
<tr>
<td>Wheat fed suddenly increases from 1 kg to 6 kg per cow.</td>
<td></td>
</tr>
<tr>
<td>Hay is fed.</td>
<td></td>
</tr>
<tr>
<td>Turnips are fed.</td>
<td></td>
</tr>
</tbody>
</table>
**EXERCISE 12.2: What is the value of a certain type of milk?** Milk prices are calculated by different methods. The table below lists different daily milk production, with differing tests for fat and protein and with one type of compositional pricing structure.

Calculate the value of each component in the milk to determine which cow's milk has the highest value.

(Round your answers to the number of decimal places shown for Cow 1; i.e. two decimal places for columns D and J, and three decimal places for columns E, F, G, H, and I.)

<table>
<thead>
<tr>
<th>FAT PRICE ($/KG)</th>
<th>PROTEIN PRICE ($/KG)</th>
<th>LITRE CHARGE ($/LITRE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.20</td>
<td>$5.00</td>
<td>$0.028</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cow</th>
<th>L</th>
<th>Fat (%)</th>
<th>Prot. (%)</th>
<th>Protein to fat ratio</th>
<th>Fat yield (kg)</th>
<th>Protein yield (kg)</th>
<th>Fat ($)</th>
<th>Protein ($)</th>
<th>Litre charge ($)</th>
<th>Total return ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>5.30</td>
<td>4.30</td>
<td></td>
<td>0.81</td>
<td>0.795</td>
<td>0.645</td>
<td>1.749</td>
<td>3.225</td>
<td>0.420</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>4.50</td>
<td>3.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>4.17</td>
<td>3.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>4.50</td>
<td>3.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>3.90</td>
<td>3.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>4.60</td>
<td>3.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>3.60</td>
<td>2.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>4.10</td>
<td>3.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>25</td>
<td>3.70</td>
<td>3.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>25</td>
<td>4.00</td>
<td>3.30</td>
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<td></td>
<td></td>
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<tr>
<td>11</td>
<td>30</td>
<td>3.70</td>
<td>3.00</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>3.60</td>
<td>2.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Highest value = Cow ______.
Chapter 12. Diet and Its Effect on Milk Production and Body Condition

The value of a cow’s daily milk depends on the total volume (litres) produced, the composition of the milk, and the pricing structure for milk. When comparing the value of milk from different breeds, from different cows, or from the same cow at different stages on different diets, this calculation needs to be made.
13 Nutrition and Fertility

Feeding strategies for dairy cows have focused primarily on achieving optimum milk production. However, as we achieve higher production per cow through better management, better genetics and better nutrition, it is clear that consideration must also be given to other aspects of cow performance. One of the most important of these is fertility.

This chapter discusses some of the ways that nutrition can affect fertility. Before discussing the effects of nutrition on reproductive performance, let’s look at how successful reproductive performance is judged.

13.1 Describing reproductive performance

<table>
<thead>
<tr>
<th>Terminology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mating start date</td>
<td>The date when mating commences in a seasonally calving herd.</td>
</tr>
<tr>
<td>Planned start-of-calving date</td>
<td>282 days after the mating start date. This is the date that a</td>
</tr>
<tr>
<td></td>
<td>cow that conceived on the mating start date would calve if she</td>
</tr>
<tr>
<td></td>
<td>had a pregnancy of normal length.</td>
</tr>
<tr>
<td>Embryo</td>
<td>The embryo is formed at fertilisation (which occurs soon after</td>
</tr>
<tr>
<td></td>
<td>the end of heat).</td>
</tr>
<tr>
<td>Foetus</td>
<td>After six weeks, the embryo is considered to have become a foetus.</td>
</tr>
</tbody>
</table>

In a seasonal calving herd, mating begins on the mating start date. This date is 282 days (ie. normal length of pregnancy) before we want the herd to start calving (the planned start-of-calving date). Except for cows with short pregnancies and abortions, the herd begins calving on the planned start-of-calving date.

After the mating start date, we expect to see a steady increase in the percentage of the herd that is pregnant. Once cows are pregnant, we want as many embryos as possible to survive, develop into foetuses and give rise to live calves.
EXAMPLE 13.1 In a 200-cow herd, the percentage of cows that are pregnant might change as described in the following table.

<table>
<thead>
<tr>
<th>Date</th>
<th>Days since mating start date</th>
<th>Number of cows pregnant</th>
<th>Percentage of herd pregnant</th>
</tr>
</thead>
<tbody>
<tr>
<td>26 Oct</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>5 Nov</td>
<td>10</td>
<td>76</td>
<td>38%</td>
</tr>
<tr>
<td>15 Nov</td>
<td>20</td>
<td>90</td>
<td>45%</td>
</tr>
<tr>
<td>18 Nov</td>
<td>23</td>
<td>100</td>
<td>50%</td>
</tr>
<tr>
<td>25 Nov</td>
<td>30</td>
<td>135</td>
<td>68%</td>
</tr>
<tr>
<td>5 Dec</td>
<td>40</td>
<td>157</td>
<td>79%</td>
</tr>
<tr>
<td>15 Dec</td>
<td>50</td>
<td>171</td>
<td>86%</td>
</tr>
<tr>
<td>25 Dec</td>
<td>60</td>
<td>180</td>
<td>90%</td>
</tr>
<tr>
<td>..........</td>
<td>..........</td>
<td>..........</td>
<td>..........</td>
</tr>
<tr>
<td>4 Mar</td>
<td>120</td>
<td>192</td>
<td>96%</td>
</tr>
</tbody>
</table>

To describe the reproductive performance for the cows in this 200-cow herd, we can look at the percentage of the herd that is pregnant at particular times after the start of mating:

- 45 per cent of the herd was pregnant by day 20 after mating start date
- 90 per cent were pregnant by day 60, and
- 96 per cent were pregnant by day 120, when mating finished
- The remaining 4 per cent were not pregnant and have to be culled or carried over.

Alternatively, we might report how long it took to reach a particular pregnancy percentage. In the Example 13.1, 50 per cent of the cows were pregnant by 23 days after mating start date.

13.1.1 Submission and conception rates

For cows to become pregnant, they must first be inseminated or served (‘submitted’ to service). Then they must conceive. So the reproductive performance of a herd is affected by both submission rates and conception rates.

Submission rate

Submission rates tell us how quickly the cows in the herd were first served.

Submission rate is the percentage of the herd which received at least one insemination in the first 10, 21, 24 or 30 days of mating.
Care needs to be taken when assessing submission rates because:

- Submission rates can be calculated for any period. We need to know what period applies when quoting submission rates.
- For this calculation, we count the number of cows inseminated, not the number of inseminations.

**EXAMPLE 13.2: Suppose there are 185 inseminations in the first 21 days of mating our 200-cow herd.**

Twenty-five cows had two inseminations in this period.

\[
185 - 25 = 160 \text{ cows received at least one insemination.}
\]

Therefore, the 21-day submission rate is \( 160 \div 200 \) or 80 per cent.

(It is not \( 185 \div 200 \) or 92.5 per cent.)

These calculations should include all cows that we want to get pregnant, even late-calving cows.

Suppose that five cows in our example herd above had not calved by the mating start date. They should be included in the 200 cows. Only cows that we don’t intend to inseminate should be excluded.

**Conception rate**

Conception rates tell us how many inseminations or services result in pregnancy.

Conception rate is the number of services resulting in pregnancy divided by the total number of services.

Again, care needs to be taken:

- There is confusion over how conception rates are calculated.
- For this calculation we count inseminations or services, not cows.
Chapter 13. Nutrition and Fertility

EXAMPLE 13.3 Suppose that in our example we used 250 straws and 150 resulted in pregnancy.

The conception rate would be 150 ÷ 250 or 60 per cent.

Conception rates can be calculated for the whole herd or for many groups within the herd. We might calculate them only for first services, only for inseminations of particular groups of cows (e.g. old cows, induced cows) or only for inseminations by particular sires.

Which inseminations resulted in pregnancy?

In order to calculate conception rates we need to know whether a service results in pregnancy. We become hopeful that a cow is pregnant if she does not return to service. The longer it is since she returned to service, the more confident we become that conception occurred.

However, some non-pregnant cows are not seen to return to service. In most herds, a number of cows thought to be pregnant to their first service actually become pregnant to later services. This applies to many cows in some herds.

To determine which inseminations resulted in pregnancy, veterinary pregnancy testing when cows are between 6 and 12 weeks of pregnancy is much more accurate than non-return to service.

Waiting until next calving is another way to find out whether the cow conceived. But this way has problems. First, cows can abort or be induced or sold before they calve. Second, the length of pregnancy can vary, so we make errors when deciding which insemination resulted in pregnancy. Third, the information is not available until months after the mating period.

13.2 Non-nutritional factors that can affect reproductive performance

Producers know that reproductive performance is affected by many factors. Nutrition is only one possible cause of poor reproductive performance. In some herds, nutrition is not the most important cause of poor performance. Some of the other causes can be divided into those that affect submission rate and those that affect conception rate.
Factors that can adversely affect submission rates include:

- Late calving cows and heifers
- Undetected heats
- Lameness
- Large numbers of young or old cows in the herd
- Poorly grown heifers
- Poor bull performance
- Insufficient number of bulls
- Inclement weather (extremes of heat or cold)
- Withholding cows from service
- Reproductive tract infections
- Cystic ovaries
- Numerous diseases
- Various other stressors (fear of operators, poor shed or yard design etc.).

Factors that may adversely affect conception rates include:

- Inseminating cows soon after calving
- Inseminating cows when not on heat
- Inseminating cows too late after heat commences
- Incorrect semen storage or handling
- Incorrect insemination technique
- Inclement weather (extremes of heat or cold)
- Poor bull or sire fertility
- Large numbers of young or old cows in the herd
- Splitting straws
- Reproductive tract infections (including vibriosis, pestivirus, IBR-IPV, leptospirosis)
- Induced calving.

Then, once the cow has conceived, there are many causes of abortion.

### 13.3 Herd calving pattern

Herd calving pattern is the single most important factor affecting herd reproductive performance. For high submission and conception rates, it is crucial that the herd has a tight calving pattern. Late calving heifers and cows are at very high risk of conceiving late or not at all.
When compared to earlier calving herd mates, heifers and cows that calve close to the mating start date are much more likely not to be pregnant 30 days after mating begins. Some will still not be pregnant at the end of mating due to reduced submission and conception rates.

This effect on submission and conception rates is shown in Table 13.1. Early calvers (cows calved at least 80 days before mating start date) are listed on the left. Columns to the right show figures for cows that calved progressively later. The less time between calving and the mating start date, the lower the submission and conception rates.

Table 13.1  Effect of late calving on subsequent conception rates to first service (Macalister Irrigation Area 1984–85).

<table>
<thead>
<tr>
<th>Days calved at mating start date</th>
<th>Calved after mating start date</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 or more</td>
<td>79–60</td>
</tr>
<tr>
<td>59–40</td>
<td>39–20</td>
</tr>
<tr>
<td>19–0</td>
<td></td>
</tr>
<tr>
<td>30 day submission rate</td>
<td>94%</td>
</tr>
<tr>
<td>Conception rate to first service</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td>61%</td>
</tr>
<tr>
<td></td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>31%</td>
</tr>
</tbody>
</table>

Herds with a spread calving pattern are really starting behind the eight ball. What can we do in herds with too many late calvers?

- Ensure that the heifers have a tight calving pattern beginning as soon as the cows begin calving. With good management, it is possible to have 75 per cent of the heifers calved in the first 30 days of calving, without beginning calving earlier than the cows.

- Ensure that the herd has a reasonable replacement rate, so that with heifers calving early we can cull more cows which are due to calve late. In some herds, a shift to a younger herd may also improve herd reproductive performance and could be a profitable option.

- Ensure that heifers are well grown and have good sized frames, so that they compete well with cows, do not lose too much condition, are less likely to become lame, and are back in calf again quickly.
• If any calvings are to be induced, use early pregnancy testing to plan the inductions and induce as early as feasible

• Manage the cows to maximise herd fertility and achieve as many conceptions in later calving cows as possible.

13.4 Effects of nutrition on the reproductive performance of dairy cows

13.4.1 Energy

Energy intake affects milk production, body condition and liveweight.

Numerous studies have investigated effects of milk production, body condition score and liveweight on fertility. Results have varied widely. To date, the effects of energy intake on fertility have not been fully clarified.

Nevertheless, some effects are clear. The effects of energy intake can be separated into effects on submission rates and effects on conception rates.

Effects of energy intake on submission rate

Research in Victoria in the 1980s (see Table 13.2) demonstrated the effect of extreme undernutrition on the onset of cycling. Cows of various breeds were calved in condition scores ranging from 3 to 6 (where 1 = emaciated and 8 = extremely fat) and were then fed 7, 11 or 15 kg DM/day of pasture for the first five weeks of lactation. After that, all groups were allocated the same amount of pasture.

Table 13.2: Effect of condition score at calving and post calving feeding on days from calving to first detected heat.

<table>
<thead>
<tr>
<th>Pasture fed after calving (kg DM/day)</th>
<th>Days from calving to first detected heat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>55</td>
</tr>
<tr>
<td>11</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>46</td>
</tr>
</tbody>
</table>

(Source: Grainger et al., 1982)
Chapter 13. Nutrition and Fertility

The first detected heat was markedly delayed among cows in poor condition at calving and cows fed very limited pasture after calving. Because of this delay, submission rates were dramatically reduced in the thin and underfed groups.

The study in Table 13.2 assesses the effects of nutrition at the low end of the scale. Large, high-producing Holstein-Friesian cows can eat 24 kg DM daily or even more if managed appropriately. It is likely that the cows in this study would have eaten well over 15 kg DM if they had been allowed. So underfeeding was occurring, even in the best fed groups in the study.

At the other extreme, cows can be too fat at calving. Cows calving in condition scores above 6 are at greater risk of fatty liver syndrome, with associated reduction in appetite, excessive weight loss and increased likelihood of retained foetal membranes and/or non-cycling. Except for some cows being carried over, cows in south-eastern Australian are rarely seen in condition scores greater than 6.

If low-producing cows are fed better both before and after calving, we achieve improved submission and conception rates and higher milk yields. Extensive work is now focusing on the effects of nutrition in high-producing cows.

Probably the best current explanation of the causes of delayed cycling among high-producing cows comes from North America. Under the systems of management there, it appears that condition loss after calving is more likely to cause delayed cycling than is the level of milk production in early lactation.

The problem, as we saw in Chapter 6, is that milk production peaks before maximum feed intake, even where cows are fed ad lib.

This means that in early lactation, cows’ energy requirements exceed their intake. They are in ‘negative energy balance’ and so they lose body condition and weight. This is seen in Figure 13.1 as the trough that occurs soon after calving. In this study, cows lost condition for the first 7 weeks of lactation.

The negative energy balance is worst in the first few weeks after calving, before slow improvement. Intake capacity
steadily increases and cows eventually move into positive energy balance. When in positive energy balance, cows begin to gain condition.

![Energy balance over weeks after calving](image)

(Source: Ferguson, 1991)

**Figure 13.1: Changes in energy balance in early and mid-lactation.**

This effect has been demonstrated with Northern hemisphere production systems. The actual levels of milk production and intake are considerably less with pasture-fed cows in Australia. However, similar effects probably occur at these lower levels of production and intake.

How does this impact on reproductive performance? Some research suggests that cows have their first ovulation about 10 days after the greatest negative energy balance. So if the negative energy balance is prolonged, first ovulation will be delayed and submission rates reduced.

Greater negative energy balance (a deeper trough in Figure 13.1) may also cause longer delays to first ovulation. The graph in Figure 13.1 is the average for the group of 40 cows. Clearly some herds will have deeper and more prolonged troughs than others, due to cow type and management.

Importantly, there is also a lot of variation between cows within herds. Higher-producing cows will generally have deeper and more prolonged troughs than lower producers.
However, the cows with the worst troughs may not be the highest producers within a herd. Cow appetite can also have large effects. Cows producing a little less but eating a lot less will clearly be at more risk. This effect may be particularly important in pasture-based production systems where cows must forage and compete for limited feed.

**Effects of energy intake on conception rates**

Energy intake and condition score affect onset of cycling after calving. Early onset of cycling clearly increases submission rates. Furthermore, early onset of cycling also increases conception rates.

New Zealand research suggests that conception rates are improved in cows which have had at least one heat before mating (Table 13.3). This is regardless of the length of time between calving and the start of mating.

**Table 13.3: Effect of pre-mating heats on first service conception rates**

<table>
<thead>
<tr>
<th>Number of pre-mating heats</th>
<th>Days from calving to first service</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 or more</td>
<td>30-39</td>
<td>Less than 30</td>
</tr>
<tr>
<td>0</td>
<td>59</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>49</td>
<td>39</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>51</td>
<td>40</td>
</tr>
</tbody>
</table>

(Source: Macmillan et al., 1980)

Hormonal changes may explain the positive effect of a heat before mating on conception. It appears that conception rates are improved by high levels of the hormone progesterone in the twelve days before insemination.

Progesterone is produced by the ovary after a cow has ovulated. Cows inseminated on their second ovulation will usually have had much higher progesterone levels for the previous twelve days.

There may also be other explanations for the improvement in conception rates among cows having a heat before mating.
Other effects of energy intake on conception rates

Energy balance may also affect conception rates in other ways. One suggestion is that negative energy balance long before insemination may reduce conception rates.

In the ovary, egg development begins around 60–100 days before the heat where the egg is released. It may be that adverse conditions around that time can result in a defective egg being produced and released.

If true, this might mean that severe weight loss in early lactation could result in poor quality eggs when cows are inseminated.

For late-calving cows which are mated soon after calving, weight loss in the dry period could have similar effects.

Some implications for management

Management in late lactation

In many herds, cows dry off in the condition in which they calve. How cows are fed in late lactation and when they are dried off will have huge effects on condition score at drying off and at calving.

Dry cow management

Dry cows must not lose weight. In some herds in Western Victoria there are large weight losses among some groups of dry cows (J. Morton, pers. comm.). This is likely to be occurring in other areas of the state as well.

Even if liveweight does not seem to be declining, cows may be losing condition. The increasing weight of the foetus and udder during pregnancy may mask losses of the cow’s own bodyweight.

Management during the transition period

Decrease in appetite around calving has to be minimised. In the past in south-eastern Australia, we have often made dramatic changes in diet as cows move from the calving paddock to the milking herd. The cow’s rumen needs time to adjust to the new diet. Digestion and intake can be reduced while the rumen is adjusting.

This adjustment can start before calving. In herds where milkers are fed moderate to large quantities of grains, lead
feeding (gradual introduction of grain in the diet before calving) helps reduce the impact of dramatic change in diet. Lead feeding may also help retain condition in the last few weeks before calving.

Anionic (‘acid’) salts may enable some pasture to be fed to springers without increasing the risk of milk fever. Feeding some pasture may help reduce the impact of the dietary changes after calving.

Minimise condition loss after calving

It is crucial that we achieve high energy intakes quickly after calving. The many considerations in feeding cows in early lactation are discussed in other sections of this manual.

Monitoring changes in condition score

A system for picking up small changes in condition score quickly is badly needed. We would get concerned about a drop of 2 L in daily milk production per cow in early lactation. This contains the same amount of energy as a daily fall in liveweight of 0.4 kg, or about 1 per cent of a condition score.

We should be just as concerned about the drop in condition score. Unfortunately, we cannot see the tiny changes in body condition that occur day to day. It would take over 50 days for that rate of condition loss to become visible!

One approach would be to have an independent person regularly score the same 20 or 30 monitor cows within the herd. These cows should be a range of ages and production levels. Scores could then be compared with previous scores.

13.4.2 Protein

Excess protein

A characteristic of our pasture-based production systems is that at certain times of the year the protein content of pasture exceeds cows’ requirements.

The excess is increased by the tendency of cows to select a diet even higher in protein than the average of the pasture sward. While there is currently much interest in the effect
of this excess protein, we should remember that pasture-fed herds have been performing satisfactorily for many years.

Even if excess protein is shown to have detrimental effects on reproductive performance, this may not outweigh the benefits of our pasture-based grazing systems.

Most of the protein in pasture is rumen degradable (RDP). Overseas research work suggests that diets high in RDP depress conception rates. Imbalance between the amounts of fermentable carbohydrate and protein in the diet may be the key concern.

Very little of this work has been completed using pasture-fed cows. A recent New Zealand study suggests that the effects of high protein pasture diets are less serious than those reported from the Northern Hemisphere. Several trials are currently under way in Australia to investigate this issue.

Diets with excess protein have effects other than on conception rates. It costs the cow energy to break down the excess protein, energy which could otherwise have been used for milk production and body condition. So, adverse effects of high protein diets on fertility may be due to an energy deficit.

Unless the cost of this imbalance is shown to be extremely high, it is unlikely that we will move away from ryegrass/white clover pastures in south-eastern Australia. However, we may ultimately be able to use some simple strategies to ensure that rumen carbohydrate, protein and fibre levels are better balanced. Current nutrient intake research work in Victoria and other states is aimed at helping sort out these very complex issues.

Current views on excess protein

When lactating cows are eating considerable quantities of high quality pasture, feeding supplements high in protein seems inappropriate and possibly harmful.

In early lactation, pasture-fed cows have very high rates of flow through the rumen. This may prevent breakdown of some of the pasture protein in the rumen so that any effects of excess protein intake from pasture are reduced by high flow rates.
If the protein ‘escapes’ breakdown in the rumen, it effectively becomes UDP (undegradable protein). At present, we do not suspect that high UDP intake affects fertility.

Theoretically, feeding fermentable carbohydrate as grains (barley, triticale, wheat) can help balance the high protein intakes and avoid the energy wasted in breaking down the excess urea.

Recent work suggests that grains such as rice that are fermented more slowly may be a better balance than other grains. However, the real effects and economics of these strategies are unclear at present.

The ‘imbalance’ between protein and fermentable carbohydrate in pasture varies. The imbalance is greatest:

• after prolonged cloudy weather
• soon after pastures are grazed, and
• early in the day.

Theoretically, longer grazing rotations may help. However, there are many other considerations in deciding on a grazing rotation.

To better balance intakes throughout the day, farmers are beginning to consider alternative ways of feeding crops and supplements. For example, feeding turnip crops after lunch, rather than immediately after the morning milking. If cows have had grain at the morning milking followed by pasture or silage, this may lessen the daily fluctuations in fermentable carbohydrate intake from grain and turnip bulbs.

**Protein deficiency**

The cow’s highest requirement for protein is in early lactation. Requirements for both rumen degradable protein (RDP) and undegradable protein (UDP) increase after calving, especially among high producing cows.

With winter or spring calving, increased RDP requirements for lactation are easily met, even with moderate pasture intakes. Under typical Victorian conditions, we would expect to see severe RDP deficiency only when pasture is severely limited. Under these circumstances, energy intake would probably be severely
limited too. The combination could then have serious
effects on herd reproductive performance.

Very high producing cows have greater UDP requirements
than do lower producers. However, effects of inadequate
UDP on fertility have not been quantified in pasture-fed
cattle.

13.4.3 Minerals, trace elements and vitamins

Cows require numerous minerals, trace elements and
vitamins to survive. The roles of minerals and vitamins
have been discussed elsewhere in this manual, so only
those implicated in fertility are mentioned here.

**Calcium**

There are suggestions that ‘sub-clinical’ calcium deficiency
in cows around calving can result in calving troubles,
retained foetal membranes and inappetence.
If correct, these effects could result in reduced
reproductive performance.

If either milk fever or ‘sub-clinical’ calcium deficiency are
considered to be problems, anionic salts could be used in
conjunction with other dry cow management strategies.
Springers should not be fed grain containing
sodium bicarbonate.

**Magnesium**

Supplementary magnesium fed to springers and calving
cows reduces the risk of grass tetany in these groups. It
also appears to reduce the incidence of milk fever. Some
advisers recommend this to avoid ‘sub-clinical’ calcium
and magnesium deficiencies in cows at calving.

**Phosphorus**

Phosphorus deficiency has been shown to cause delayed
onset of heat in some studies but not others. Phosphorus-
deficient cattle can also be energy-deficient in some
circumstances (e.g. during prolonged drought). In these
situations, effects of phosphorus deficiency cannot be
readily determined.

In early lactation, phosphorus supplied in the pasture may
sometimes be insufficient to meet cows’ requirements.
Affected cows then use their bone reserves of phosphorus.
This may be sufficient to prevent reproductive performance being affected.

**Selenium**

Although many Victorian cows have low blood test results for this element, reproductive performance does not appear to be increased by supplementation. There are numerous reports of retained foetal membranes due to selenium deficiency. Unfortunately, most of these studies used cattle managed under Northern Hemisphere conditions. The incidence of retained foetal membranes does not appear to be increased in Victorian herds despite widespread ‘low’ selenium levels. Growth responses in heifers to selenium supplementation may occur in some conditions.

**Detecting deficiencies**

Laboratory tests are available for many minerals and trace elements. While some tests are useful, the results of other tests are not highly correlated with responses to treatment.

In other words, even if testing indicates a deficiency, supplementation does not always produce an improvement in animal performance.

Feed analyses might help to estimate an animal’s current intake of certain elements, but there are some drawbacks:

- Results will vary between feed batches and even between paddocks on the same farm
- Cows graze selectively, so sampling has to mimic this in order to estimate what is actually being eaten
- Feed intake has to be estimated
- Minerals interact with each other. Requirements for most minerals and trace elements depend on how much of other minerals and trace elements are present.

Meaningful interpretation of feed analyses for minerals and trace elements is not simple.
14. **Nutrition and Dairy Replacements**

Well-grown dairy heifers are a good investment in the milking herd. To ensure they grow to become high-yielding and efficient dairy cows, their management is carefully planned and begins the day they are born.

A well-managed heifer rearing system aims for:

- Good animal performance with minimal disease and mortality
- Optimum growth rates to achieve target liveweights
- Minimum costs of inputs, such as feed (milk, concentrates and forages), animal health needs (veterinary fees and drugs) and other operating costs (milk-feeding equipment) to achieve well-reared heifers
- Minimum labour requirements
- Maximum utilisation of existing facilities such as sheds for rearing and pastures for grazing.

There is no single best way to milk-rear calves. All sorts of combinations of feeding, housing and husbandry can be successful in the right hands and on the right farm. Successful calf rearing is a specialist job requiring suitable facilities. It also requires a genuine concern for the welfare of young calves and quick responses to early symptoms of disease. If dairy farmers are unable to commit the time and resources to rearing their own replacement heifers, they should seriously consider paying someone who is better placed to do a good job.

The first three months are the most expensive period in the life of any dairy cow. During that time, mortality rates are high – up to 10 per cent in many cases – although 2–4 per cent is considered acceptable. Calves need protection from the extremes of sun, wind and rain no matter what the rearing system. Disease prevention and treatment can be costly during early life.

### 14.1 Rearing the milk-fed calf

With their undeveloped digestive tract, calves require the highest quality and the most easily digestible source of
Chapter 14. Nutrition and Dairy Replacements

nutrients, namely, whole milk or milk replacers. Unfortunately, these are also the most expensive feeds.

As a source of feed energy, milk is two to three times more expensive than concentrates and 20 times more expensive than grazed pasture. The most effective way of minimising the high feed costs of calf rearing is through early weaning and reduced milk feeding.

The essence of good calf rearing depends on two major nutritional factors. First, an adequate intake of high quality colostrum within the first day of life and, second, feeding management to encourage early rumen development.

14.1.1 Colostrum feeding

Newborn calves are very susceptible to disease. Before they can develop their own immunity they are entirely dependent on the antibodies contained in their mother’s milk. It is therefore vital that they receive adequate quantities of antibody-rich colostrum from their mothers or from other freshly calved cows.

Calves should have access to at least four litres of colostrum within the first six hours of life. They will not need any additional milk for the next 12–24 hours. Any calf that is suspected of not having suckled in the first 3–6 hours should be hand-fed colostrum. With sick or weak calves, colostrum may have to be administered by stomach tube. It is not difficult to stomach-tube young calves when using commercially available fluid feeders specifically designed for the purpose.

Frozen colostrum (which can be stored for 18 months) can be thawed out and used, or colostrum from a mature cow within the herd can be fed. Fresh colostrum can be stored for 7–10 days. Colostrum should be tested for antibody concentration to ensure it is of sufficient quality to store.

The level of immunity passed on by the cow increases with her age, since older animals have been exposed to a greater range of infectious organisms to which they have developed antibodies. Replacement heifers born to first calving cows may require additional stored colostrum from older cows to ensure they develop good disease immunity. The immune properties of colostrum can be enhanced by vaccinating cows prior to calving for *E. coli*, Clostridia and Salmonella.
The longer calves spend with their dams, the greater their chances of contracting disease. The practice of ‘snatch calving’ (removing the calf from the cow immediately after birth) increases the labour requirements during the busy calving period and may not be adopted by farmers with seasonal-calving herds unless there are obvious benefits through reduced health problems (such as Johne’s disease) and mortality.

14.1.2 Early rumen development

The rumen is non-functional in newborn calves; hence, all digestion must take place in the abomasum (or true stomach) and the small intestine. The weaned calf needs a fully functional rumen in order to be well adapted to a herbage diet. Before weaning, it is important to promote rumen development, so as to avoid growth checks when calves are weaned.

Rumen development occurs through the digestion or fermentation of feeds (roughages and concentrates) by the rumen microbes (the end products being volatile fatty acids). Calves should be encouraged to eat solid feeds at an early age, mainly through limiting their access to milk to 4 L/day. From the first week, roughage such as clean straw should be offered in combination with high-quality concentrates or calf-rearing pellets.

Grazed pasture is not an ideal source of roughage for milk-fed calves. Pasture contains too little fibre, and its very high water content prevents high intakes of feed energy in each mouthful. This limits the feed energy available for rapidly growing animals.

Until their rumen capacity is larger, young calves just cannot eat enough pasture to sustain high growth rates.

14.2 A successful early weaning recipe for calf rearing

Dairy farmers generally want to feed their calves on the best quality feeds to give the calves a good start to life. On the whole though, most dairy farmers feed too much milk for too long.

By continuing to feed milk longer than is necessary, farmers often feed 400–500 litres of milk to each calf. They should only feed 200 litres of milk or less. Furthermore,
much of this milk can be colostrum from calving cows, making the milk costs very low.

If calves are strong, healthy and kept warm and dry, they can be successfully reared on once-daily feeding with four litres of whole milk, or its equivalent in milk replacer. Such calves should be offered palatable calf pellets or specially formulated meal from one week of age.

Calves should have limited access to fresh pasture (and preferably no access at all). The key to this rearing system is giving the calves continuous access to clean straw as a source of roughage. Note this is clean straw, not good quality pasture hay or lucerne hay.

All calves must be given the opportunity to nibble on the straw even though they will eat very little of it. Straw will encourage rumen development rather than provide nutrients.

If better quality hay is fed in place of straw, calves will eat more roughage but at the expense of concentrate consumption. If good quality hay is fed, it should be limited to 100–200 g/calf/day. Clean drinking water must be available at all times.

Feeding milk only once each day helps the calves to develop an appetite for the pellets. It is the pellets rather than the milk that provide the bulk of nutrients to keep the calf growing. Calves can be weaned off milk once they are consuming 0.75 kg/day of pellets for two or three consecutive days. This usually occurs by about six weeks of age.

Provided calves are eating 0.75 kg/day of pellets, milk feeding does not have to be reduced gradually. Calves should continue to be housed indoors during weaning. They can go out to pasture a few days after weaning.

This system rears the rumen rather than the calf. Systems that involve feeding more milk do not encourage early rumen development and hence calves must be older before they can continue to grow without milk.

It is important that each calf drinks its allocation of milk. Lower milk intakes will limit calf performance because of the inability of the young animal to compensate by eating more pellets. As well as reducing growth rates, underfed
calves may be more susceptible to diseases and other stresses during life.

Higher milk intakes will discourage pellet consumption. If calves are weaned in large groups based on the average pellet intake of the group (together with an assessment of liveweight), the calves consuming large volumes of milk and little pellets can have underdeveloped rumens.

Ideally, calves should be housed individually or in small groups. They should also be individually bucket-fed. There is no advantage in milk feeding using teats rather than buckets; it only creates extra work in keeping them clean.

### 14.2.1 Criteria for successful calf-rearing systems

As already mentioned there are many ways to successfully rear calves.

A calf-rearing system should produce fully weaned calves, weighing 100 kg, at 12 weeks of age. This weight criterion is equivalent to a growth rate of 0.7 kg/day.

Weight tapes or wither height sticks can be used as a guide to calf liveweights, but tend to overestimate weight.

Unless the rumen is well developed at weaning, calves will not be able to utilise dry feed once milk feeding has ceased. They will suffer a post-weaning growth check. High levels of milk feeding with no calf pellets fed at all can produce calves weighing 100 kg at 12 weeks but not fully prepared for weaning.

It is also more costly to rear calves this way. Table 14.1 shows the cost of dry matter and energy in some of the feeds commonly used for calves. Costs fluctuate and feed composition varies, so the table is only a guide.
Table 14.1: Costs of dry matter and energy in calf feeds.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry matter (%)</th>
<th>Energy (MJ/kg DM)</th>
<th>Crude protein (%)</th>
<th>Cost per unit</th>
<th>DM cost (c/kg)</th>
<th>Energy cost (c/MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid feeds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole milk *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- cheap</td>
<td>13</td>
<td>22.3</td>
<td>23</td>
<td>20c/L</td>
<td>154</td>
<td>6.9</td>
</tr>
<tr>
<td>- expensive</td>
<td>13</td>
<td>22.3</td>
<td>23</td>
<td>30c/L</td>
<td>230</td>
<td>10.3</td>
</tr>
<tr>
<td>Milk replacer **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- cheap</td>
<td>96</td>
<td>20.2</td>
<td>26</td>
<td>$45/bag</td>
<td>234</td>
<td>12.0</td>
</tr>
<tr>
<td>- expensive</td>
<td>96</td>
<td>20.2</td>
<td>26</td>
<td>$55/bag</td>
<td>286</td>
<td>14.6</td>
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<td><strong>Concentrates</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pellets</td>
<td>90</td>
<td>13</td>
<td>8</td>
<td>$350/t</td>
<td>38</td>
<td>2.9</td>
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<tr>
<td>Farm mix</td>
<td>90</td>
<td>13</td>
<td>18</td>
<td>$260/t</td>
<td>29</td>
<td>2.2</td>
</tr>
</tbody>
</table>

(Source: Moran, 1996)

* Assumes 4% fat and 3% protein
** Assumes 20% fat and 25% protein

**EXERCISE 14.1: Calculating the costs of your own calf feeds.**

Using the worksheet at the end of this chapter, calculate the costs of the nutrients in the calf feeds you use on your own farm.

14.3 Management of weaned replacement heifers

All too often, dairy farmers rear their heifer calves carefully until weaning but neglect them thereafter. There is little truth in the idea that ‘small weaned calves are cheap to produce and all that is needed to make them into good heifers is a drench and a good feed’. 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 fat. Most of the growth in skeletal size occurs before, not after puberty.

Weaned heifers do, however, require less attention than milk-fed calves and milking cows. From weaning until joining and sometimes even after that, daily contact is not necessary. Because their nutrient requirements are lower than those of lactating cows, heifers are often located away from the prime grazing areas on the farm, such as on ‘runoff’ blocks or on agistment. However, dairy heifers
need to be well fed between weaning and first calving. If growth rates are not maintained, heifers will not reach their target liveweights for mating and first calving. In the case of replacement heifers, ‘out of sight’ should not mean ‘out of mind’.

Undersized heifers have more calving difficulties, produce less milk and have greater difficulty getting back into calf during their first lactation. When lactating, they compete poorly with older, bigger cows for feed. Because they are still growing, they use feed for growth rather than for milk. Therefore they are more likely to be culled for poor milk yield and/or infertility. Many studies have demonstrated the benefits of well grown heifers in terms of fertility and milk production.

14.3.1 Fertility

The onset of puberty, and commencement of cycling, is related to liveweight more than to age. A delay in puberty means later conception, which disrupts future calving patterns. All heifers should achieve their target weight before joining, because lighter heifers have lower conception rates. Target liveweights at mating and first calving are discussed below. Calving problems depend more on heifer liveweights at mating, than on liveweights or body condition at calving. Frame size is determined early, so there is doubtful merit in the practice of feeding older heifers to make up for poor growth earlier in life (‘catch-up feeding’).

In an Irish study, heifers mated below 260 kg had 34 per cent conception to first insemination compared to 58 per cent for heifers of 300 kg or more. Of the smaller heifers, 24 per cent had difficult calvings. This declined to 8 per cent in heifers mated at 260–280 kg and was lowest in 340–360 kg heifers. Heifers under-weight at mating required considerable assistance if in difficulty during calving.

14.3.2 Milk production

Tasmanian researchers found that by increasing calving liveweights from 360 kg to 460 kg, milk production during the first lactation rose by 400 litres (Freeman, 1993). This production benefit extended into both the second lactation, with an extra 830 litres of milk/100 kg, and the third lactation, with an extra 840 litres of milk/100 kg live weight. Recent studies in northern Victoria and central NSW with heavier heifers, showed that when heifers calve...
100 kg heavier than the ones with which they were being compared, their peak production was 5 L/day higher during the first lactation. This corresponds to an extra 1000 L of milk in their first lactation, if full lactation yields are estimated by multiplying peak daily yields by 200. In other words, if heifers calving down at 425 kg peak at 20 litres/day, and produce 4000 litres in their first lactation, they would peak at 25 litres/day and have first lactation yields of 5000 litres, if they calved down at 525 kg.

14.3.3 Heifer wastage

Poorly grown heifers do not last long in the milking herd. Recent studies in Gippsland indicate that at least one third of all heifers reared are lost before their second lactation. Heavier heifers are less likely to be culled for poor milk yield or poor fertility during their first lactation.

Total herd costs can be greatly increased by this high rate of wastage. Producers should aim to lose no more than 20 per cent of their replacement heifers between weaning and their second lactation.

14.4 Critical period for udder development

A critical period for the developing udder comes when excessive growth rates may increase the deposition of fatty tissue in the udder and reduce lifetime productivity. Exactly when this critical period occurs and exactly what constitutes excessive growth rates has yet to be clearly defined, although there are some general guidelines. Some advisers consider that liveweight gains should not exceed 0.5 kg/day between six to 12 months, while others recommend gains of less than 0.7 kg/day between three to eight months of age. This still needs clarification. But it seems that excessive feeding should be avoided during the heifers’ second six months of life.

Nevertheless, the risk of fatty udder syndrome does not justify underfeeding.

Excessive growth rates are unlikely to be a problem in heifers fed a pasture-based diet, particularly for spring-calving herds, as the critical period coincides with autumn and winter, a time of seasonal pasture shortages.

At high growth rates, excess energy relative to the amount of protein in the diet may predispose heifers to fatty udder
syndrome. Balancing dietary nutrients, such as supplying bypass protein to match the energy supply in the diet, may be one way of maintaining high growth rates in heifers without causing fatty udders.

14.5 Targets for replacement heifers

14.5.1 Live weight

There is now evidence suggesting that traditional target weights are too low to ensure first lactation heifers achieve their productivity potential, particularly on farms where milking cows are well fed. Table 14.2 summarises revised and traditional target weights for Jersey and Friesian heifers at various ages. The revised target weights for Friesians more closely match the US guidelines. This seems logical because Australian Friesians have become genetically closer to the US Holsteins.

Table 14.2: Traditional and revised target weights for Jersey and Friesian heifers at different ages.

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Target weight (kg)</th>
<th>Jersey</th>
<th>Friesian</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traditional</td>
<td>Revised</td>
<td>Traditional</td>
</tr>
<tr>
<td>2-3 (weaning)</td>
<td>45–65</td>
<td>65–85</td>
<td>65–85</td>
</tr>
<tr>
<td>24 (pre-calving)</td>
<td>320–350</td>
<td>380–410</td>
<td>410–430</td>
</tr>
</tbody>
</table>

Puberty occurs in dairy heifers at 35–45 per cent of mature weight, while conception can occur at 45–50 per cent of mature weight. A dairy cow will attain her mature liveweight in about the fourth lactation and the objective of rearing heifers is to produce an animal 80–85 per cent of mature liveweight by first calving. Current guidelines for dairy heifer liveweights should be easily achievable on well managed dairy farms. Unfortunately, they are sometimes used as the average rather than the minimum, meaning that many heifers are still too light.

Because of the importance of attaining growth targets, farmers should consider how they can acquire scales for weighing cattle. Cattle scales with digital readouts can be purchased for $1000 or hired from some herd improvement organisations.
The scales can have many other uses on a dairy farm. As well as monitoring the weights of replacement heifers, they can be used to calculate drenching rates for stock, check changes in liveweight of the milking herd during different stages of lactation or even to weigh bales of hay or silage.

Wither height sticks or chest girth tapes are an alternative to scales but they are not as accurate and tend to overestimate liveweights.

### 14.5.2 Wither height

Wither height is a good measure of bone growth and frame size in heifers. Frame size can influence ease of calving and appetite of milking cows.

Producers should aim for wither heights of 125 cm at mating and 135 cm at calving. For Jerseys, the corresponding target wither heights are 115 cm at mating and 125 cm at calving.

### 14.6 Energy and protein requirements for heifers

Table 14.3 shows the energy requirements (for maintenance and growth) of heifers growing at different rates at various liveweights. The growth rates for 500 kg heifers assume a contribution of 0.4 kg/d from the growing foetus.

Growing heifers require a constant source of protein for optimum bone and muscle growth. Table 14.3 also lists crude protein requirements at different liveweights.
Chapter 14. Nutrition and Dairy Replacements

Table 14.3: Energy and protein requirements for growing heifers

<table>
<thead>
<tr>
<th>Liveweight</th>
<th>Energy requirement (MJ/day)</th>
<th>Crude protein requirement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>100</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>200</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>300</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>400</td>
<td>75</td>
<td>79</td>
</tr>
<tr>
<td>500</td>
<td>91</td>
<td>95</td>
</tr>
</tbody>
</table>

(Source: NRC, 1989)

14.7 Feeding heifers to achieve target liveweights

Recommendations for grazing and feeding systems will differ between regions. Rather than depend on recipes, producers should regularly weigh their young stock, then vary feeding strategies according to their growth rates. Growth should average 0.7 kg/day, although that can vary between 0.5 and 1.0 kg/day, depending on available pasture and the supply and cost of suitable supplements.

14.7.1 Grazed pasture feeding

As grazed pasture is the cheapest feed, it should constitute the bulk of the diet, with hay, silage or concentrates used to overcome pasture shortages. Grazed pastures or conserved hay or silage must be of sufficient quality (at least 10 MJ/kg DM) to satisfy the requirements for growth and maintenance.

Until calves 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 even top quality hay. Their capacity is limited and they simply cannot eat enough dry matter from the pasture or hay to meet their nutrient requirements for rapid growth. Pasture must be ‘top quality’ (at least 11 MJ/kg DM) if used as the sole feed for heifers less than 12 months of age.

Pasture quality and allocation should allow for continuous growth throughout the first two years. Uniform growth is not necessary and may be impracticable with fluctuating pasture availability.

Yearling heifers have the ability for compensatory gain following periods of mild undernutrition, such as during
the spring flush of pasture growth following feed shortages the preceding winter. However, heifers should not be allowed to lose weight or to grow very slowly for long periods of time (ie. no more than two weeks).

### 14.7.2 Feeding supplementary grain

Achieving 100 kg extra liveweight at two years of age requires the equivalent of 800 kg of cereal grain. For example, Friesian heifers might be grown to 525 kg instead of 425. If dairy farmers can produce fully weaned calves weighing 100 kg by twelve weeks of age, each heifer then needs to gain 425 kg over the next 21 months or an average of 0.67 kg/day. As was described above, lifetime benefits from 100 kg heavier heifers can be 3000–4000 litres of extra milk worth up to $1000 per animal.

Producers can afford to feed an extra 1.0 to 1.5 kg/day supplementary grain per heifer to attain this growth. 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 grain is available to fill in any feed gaps during the remaining 15 months.

Many types of concentrates can be fed to supplement grazing heifers. Provided pasture quality is adequate (at least 10.5 MJ/kg), the cheapest and easiest grain to feed is whole oats as it need not be rolled before feeding. A rule of thumb used by irrigated beef producers was to feed whole oats at 1 per cent of live weight when steer growth rates fell below 1 kg/day. A similar rule of thumb for dairy farmers might be, whole oats fed at one per cent liveweight when heifer growth rate falls below 0.5 kg/day.

### 14.8 Introducing replacement heifers to the herd

Before calving, heifers were non-lactating animals continuously at pasture; once they calve they become lactating animals with regular human contact twice each day.

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 condition as well as get them used to being handled. They
could also be run quietly through the milking shed a few times before calving to settle them into the milking routine.

Heifers receive immunity through routine vaccination. Heifers that graze with older cows are exposed to a greater range of infectious agents and hence develop immunity to the diseases carried by these cows as well. This immunity can then be transferred to newborn calves by antibodies in the heifers’ colostrum. If the milking herd has a history of Johne’s disease or if there is a high chance that Johne’s carrier cows have been introduced to the herd, then grazing options for young heifers are reduced.

Heifers reared in complete isolation from cows are likely to pick up infections as they calve and come in contact with the milking herd for the first time. This coincides with the time when they should be in peak health to produce milk, get back in calf early and also overcome any stresses associated with their radical change in management.

14.9 Agisting heifers off farm

Agisting young stock off the farm allows dairy farmers to use all available resources (feed, land and labour) to produce milk while still having control over the disease status of the heifers and the genetic progress in the herd.

Farmers must be well aware however, of the supply and quality of pasture for their agisted stock, the responsibility for stock health while away from the farm and the security of the agistment area against theft and straying heifers as well as neighbouring bulls.

When a site appears to meet these requirements, then the major factors that need to be taken into account are the cost of agistment and its proximity to the home farm. Agistment works well provided that it is cost-effective and heifer growth is monitored to ensure target weights are achieved.

Another option for off-farm rearing is for farmers to contract specialist cattle producers to rear their heifers and return them prior to calving.
14.10 Economic benefits from well-grown heifers

Replacement heifers are expensive to rear to first calving. After considering the cost of producing the calf ($100), its rearing to weaning ($100–150), feed costs to first calving ($250–300) plus mating and health care ($100–150), most producers will pay $600–700 before each heifer starts ‘paying her way’.

The economic benefits from higher milk production, better fertility and lower culling rates justify the additional costs of better rearing systems. For Friesians, an extra $100 spent in rearing each heifer to calve at 520–550 kg could return three- to four-fold over that cow’s productive life.
Worksheet 3: The cost of nutrients in feeds  
(Exercise 14.1)

<table>
<thead>
<tr>
<th>Feed 1:</th>
<th>Feed 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost per kg DM</strong></td>
<td><strong>Cost per kg DM</strong></td>
</tr>
<tr>
<td>kg bought (i)</td>
<td>kg bought (i)</td>
</tr>
<tr>
<td>DM %</td>
<td>DM %</td>
</tr>
</tbody>
</table>
| \( X \) | \( X \)
| \( \div 100 \) | \( \div 100 \)
| \( = \) | \( = \) |
| kg DM bought | kg DM bought |
| \( B \) | \( B \) |
| **Cost of (i) ($)** | **Cost of (i) ($)** |
| kg DM bought (from A) | kg DM bought (from A) |
| \( \div 100 \) | \( \div 100 \)
| \( = \) | \( = \) |
| c/kg DM | c/kg DM |
| **Cost per MJ ME** | **Cost per MJ ME** |
| c/kg DM (from B) | c/kg DM (from B) |
| MJ ME/kg DM | MJ ME/kg DM |
| \( \div \) | \( \div \)
| \( = \) | \( = \) |
| c/MJ ME | c/MJ ME |
| **Cost per kilogram crude protein (or NDF)** | **Cost per kilogram crude protein (or NDF)** |
| c/kg DM (from B) | c/kg DM (from B) |
| CP % (or NDF %) | CP % (or NDF %) |
| \( \times 100 \) | \( \times 100 \)
| \( = \) | \( = \) |
| c/kg CP (or c/kg NDF) | c/kg CP (or c/kg NDF) |

\( ^\dagger \)To convert dollars per kilogram to cents per kilogram.
15. Case Study

Replace this page with the Case Study pages.
Appendix A: Answers to Exercises

Exercise 3.1: How much dry matter is in a feed? 
Calculate and fill in the last two columns in the table below.

<table>
<thead>
<tr>
<th>Type of feed</th>
<th>Feed as-fed (kg)</th>
<th>Moisture (%)</th>
<th>Dry matter (%)</th>
<th>Dry matter (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td>88</td>
<td>83</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Silage</td>
<td>50</td>
<td>60</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Hay</td>
<td>20</td>
<td>20</td>
<td>80</td>
<td>16</td>
</tr>
<tr>
<td>Wheat</td>
<td>16.7</td>
<td>10</td>
<td>90</td>
<td>15</td>
</tr>
</tbody>
</table>

Exercise 3.2: The energy intake from various feeds. 
Which cow is eating the most energy? 
...Deidre... (cow's name)

<table>
<thead>
<tr>
<th>Cow</th>
<th>Type of feed</th>
<th>Intake (kg DM)</th>
<th>Energy content (MJ/kg DM)</th>
<th>Energy intake (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amy</td>
<td>Pasture</td>
<td>15</td>
<td>11</td>
<td>165</td>
</tr>
<tr>
<td>Bossy</td>
<td>Silage</td>
<td>15</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>Chloe</td>
<td>Hay</td>
<td>10</td>
<td>8.5</td>
<td>85</td>
</tr>
<tr>
<td>Deidre</td>
<td>Wheat</td>
<td>8</td>
<td>13</td>
<td>104</td>
</tr>
</tbody>
</table>
### Exercise 3.3: Energy content of feeds and milk production.

**What does the energy content of the feed need to be to reach the milk production target?**

**Write your answers in the last column of the table.**

<table>
<thead>
<tr>
<th>Cow</th>
<th>Target milk yield (L/day)</th>
<th>A Estimated energy required (MJ/day)</th>
<th>B Possible intake (kg DM/day)</th>
<th>C Required energy content of feed (MJ/kg DM) $(A + B)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>170</td>
<td>15</td>
<td>11.3</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>186</td>
<td>15</td>
<td>12.4</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>198</td>
<td>17</td>
<td>11.6</td>
</tr>
</tbody>
</table>
Exercise 5.1: What are the daily energy requirements of these cows?

Lactating animals are walking 2 km per day to the dairy on flat terrain.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cow 1</th>
<th>Cow 2</th>
<th>Cow 3</th>
<th>Cow 4</th>
<th>Cow 5</th>
<th>Cow 6</th>
<th>Cow 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (kg LWt)</td>
<td>500</td>
<td>550</td>
<td>450</td>
<td>600</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td>7th</td>
<td>Empty</td>
<td>6th</td>
<td>9th</td>
<td>7th</td>
<td>7th</td>
<td>Empty</td>
</tr>
<tr>
<td>Daily milk prod'n (L)</td>
<td>13</td>
<td>27</td>
<td>18</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Fat test (%)</td>
<td>4.4</td>
<td>4</td>
<td>5.2</td>
<td>-</td>
<td>4.8</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Protein test (%)</td>
<td>3.4</td>
<td>3.2</td>
<td>3.6</td>
<td>-</td>
<td>3.6</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>LWt gain / loss (kg/d)</td>
<td>+1.5</td>
<td>-1</td>
<td>0</td>
<td>+2</td>
<td>+1.5</td>
<td>0</td>
<td>+1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Cow 1</th>
<th>Cow 2</th>
<th>Cow 3</th>
<th>Cow 4</th>
<th>Cow 5</th>
<th>Cow 6</th>
<th>Cow 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td>54</td>
<td>59</td>
<td>49</td>
<td>63</td>
<td>54</td>
<td>54</td>
<td>54</td>
</tr>
<tr>
<td>Activity</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>10</td>
<td>0</td>
<td>8</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Milk production</td>
<td>74</td>
<td>143</td>
<td>113</td>
<td>0</td>
<td>13x6</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>=78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight gain or loss</td>
<td>66</td>
<td>-28</td>
<td>0</td>
<td>110</td>
<td>1.5x44</td>
<td>0</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>=66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy requirements</td>
<td>206</td>
<td>176</td>
<td>172</td>
<td>195</td>
<td>210</td>
<td>131</td>
<td>187</td>
</tr>
</tbody>
</table>
Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 6.1a)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>For maintenance (Table 5.1)</td>
<td>I 54 MJ</td>
<td>Early lactation 16–18%</td>
</tr>
<tr>
<td>Daily activity level</td>
<td>For activity</td>
<td>J 20 MJ</td>
<td>Mid-lactation 14–16%</td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td>5 MJ/km</td>
<td>from B km</td>
<td>Late lactation 12–14%</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td>For pregnancy (Table 5.2)</td>
<td>L 0 MJ</td>
<td>Dry 10–12%</td>
</tr>
<tr>
<td>Daily milk production</td>
<td>For milk production (Table 5.3)</td>
<td>M 138 MJ</td>
<td>30%(NDF)</td>
</tr>
<tr>
<td>Volume</td>
<td>25 litres</td>
<td>from E MJ/L</td>
<td></td>
</tr>
<tr>
<td>Fat test</td>
<td>4.2%</td>
<td>25 X 5.5 = 138 MJ</td>
<td></td>
</tr>
<tr>
<td>Protein test</td>
<td>3.4%</td>
<td>from E</td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>For or from condition (Table 5.5)</td>
<td>N -28 MJ</td>
<td></td>
</tr>
<tr>
<td>gain + loss</td>
<td>from H MJ/kg</td>
<td>-1 X 28 = -28 MJ</td>
<td></td>
</tr>
<tr>
<td>kg/cow/day</td>
<td>from above</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total daily needs of this cow:
- Energy: 184 MJ
- Crude protein: 16-18%
- NDF fibre: 30%
Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 6.1b)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td><strong>A</strong> 500 kg</td>
<td>For maintenance (Table 5.1)</td>
<td><strong>I</strong> 54 MJ</td>
</tr>
<tr>
<td>Daily activity level</td>
<td><strong>B</strong></td>
<td>For activity</td>
<td><strong>J</strong> MJ</td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td><strong>1</strong> MJ/km</td>
<td>from B km</td>
<td>= <strong>2</strong> MJ</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td><strong>D</strong> - th month</td>
<td>For pregnancy (Table 5.2)</td>
<td><strong>L</strong> 0 MJ</td>
</tr>
<tr>
<td>Dry</td>
<td>10–12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early lactation</td>
<td>16–18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-lactation</td>
<td>14–16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late lactation</td>
<td>12–14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td><strong>D</strong> - th month</td>
<td>For pregnancy (Table 5.2)</td>
<td><strong>L</strong> 0 MJ</td>
</tr>
<tr>
<td>Dry</td>
<td>10–12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early lactation</td>
<td>16–18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-lactation</td>
<td>14–16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late lactation</td>
<td>12–14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily milk production</td>
<td><strong>E</strong> 15 litres</td>
<td>For milk production (Table 5.3)</td>
<td><strong>M</strong> 85.5 MJ</td>
</tr>
<tr>
<td>Fat test</td>
<td><strong>4.4</strong> %</td>
<td>from E MJ/L</td>
<td>= <strong>5.7</strong></td>
</tr>
<tr>
<td>Protein test</td>
<td><strong>3.4</strong> %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td><strong>H</strong> 0 kg/cow/day</td>
<td>For or from condition (Table 5.5)</td>
<td><strong>N</strong> 0 MJ</td>
</tr>
<tr>
<td>from H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total daily needs of this cow:</td>
<td><strong>I</strong> 141.5 MJ</td>
<td><strong>Crude protein 14–16</strong> %</td>
<td><strong>NDF fibre 30</strong> %</td>
</tr>
</tbody>
</table>
Exercise 9.1: Use your knowledge of the nutritive value of feeds and minimum cow requirements to solve the following problems:

a) For each nutrient category, rank the feeds in boxes A–H from highest to lowest. Write the corresponding letter in the appropriate cell of the table.

b) Which feeds, on their own, would meet the minimum requirements of a 500 kg cow in early lactation producing 25 L of milk with 4.2 per cent fat and 3.4 per cent protein? Use Worksheet 1 to help you calculate the cow’s requirements.

Minimum requirements would be 191.5 MJ ME per day, with 16 per cent CP and 30 per cent NDF.

<table>
<thead>
<tr>
<th>FEEDTEST Results</th>
<th>A Late hay</th>
<th>B Early silage</th>
<th>C Turnips</th>
<th>D Dairy pellets</th>
<th>E Wet brewers grain</th>
<th>F Good autumn pasture</th>
<th>G Poor autumn pasture</th>
<th>H Barley/ lupin mix (20% lupin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture %</td>
<td>9.8</td>
<td>58.1</td>
<td>90.2</td>
<td>9.7</td>
<td>76.7</td>
<td>82</td>
<td>77.5</td>
<td>9.2</td>
</tr>
<tr>
<td>DM %</td>
<td>90.2</td>
<td>41.9</td>
<td>9.8</td>
<td>90.3</td>
<td>23.3</td>
<td>18</td>
<td>22.5</td>
<td>90.8</td>
</tr>
<tr>
<td>CP %</td>
<td>6.3</td>
<td>18.2</td>
<td>19.5</td>
<td>14.0</td>
<td>18.5</td>
<td>22</td>
<td>18</td>
<td>13.5</td>
</tr>
<tr>
<td>NDF %</td>
<td>60</td>
<td>35</td>
<td>20</td>
<td>15</td>
<td>40</td>
<td>30</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>Digestibility %</td>
<td>54.9</td>
<td>70.3</td>
<td>91.5</td>
<td>79.7</td>
<td>71.6</td>
<td>75</td>
<td>70</td>
<td>83.5</td>
</tr>
<tr>
<td>MJ / kg DM</td>
<td>7.3</td>
<td>10</td>
<td>13.6</td>
<td>11.4</td>
<td>10.2</td>
<td>10.8</td>
<td>9.9</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Feeds that would potentially meet these requirements are early silage, wet brewers grain, and both good or poor autumn pasture. Of these, it is most possible from the good autumn pasture because it has the highest energy density (ie., less needs to be eaten to achieve adequate energy intake). The cow would have to eat around 18 kg DM/d of good autumn pasture versus 19.5 kg DM/d of poor autumn pasture.
### Worksheet 1: The daily energy, protein and fibre needs of a cow (Exercise 11.1)

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>For maintenance (Table 5.1)</td>
<td>I</td>
<td>59 MJ</td>
</tr>
<tr>
<td><strong>A</strong> 550 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily activity level</td>
<td>For activity</td>
<td><strong>J</strong></td>
<td>5 MJ</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>1 MJ/km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td>from <strong>B</strong> km</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>D</strong> - th month</td>
<td>For pregnancy (Table 5.2)</td>
<td><strong>L</strong></td>
<td>0 MJ</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E</strong> Volume 25 litres</td>
<td>For milk production (Table 5.3)</td>
<td><strong>M</strong></td>
<td>143 MJ</td>
</tr>
<tr>
<td><strong>F</strong> Fat test 4.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>G</strong> Protein test 3.2%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>For or from condition (Table 5.5)</td>
<td><strong>N</strong></td>
<td>-42 MJ</td>
</tr>
<tr>
<td><strong>H</strong> gain + loss -1.5 kg/cow/day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total daily needs of this cow:</td>
<td>Energy</td>
<td><strong>165</strong> MJ</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crude protein 16-18%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NDF fibre 30%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Early lactation 16-18%
Mid-lactation 14-16%
Late lactation 12-14%
Dry 10-12%
30%(NDF)

Appendix A: Answers to the Exercises
<table>
<thead>
<tr>
<th></th>
<th>Dry matter</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td>A</td>
<td>10</td>
<td>J</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>kg DM/cow/day</td>
<td>from A</td>
<td>MJ/kg DM</td>
<td>from A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MJ/cow/day</td>
<td>from feed test</td>
<td>from feed test</td>
</tr>
<tr>
<td>Supp 1</td>
<td>B</td>
<td>7 x 28.8</td>
<td>2 x 8</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>kg/cow/day</td>
<td>from A</td>
<td>from B</td>
<td>from B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MG DM/cow/day</td>
<td>MG DM/cow/day</td>
<td>protein %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>Supp 2</td>
<td>C</td>
<td>5.6 x 89.8</td>
<td>5 x 12.8</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>kg/cow/day</td>
<td>from A</td>
<td>from B</td>
<td>from B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MG DM/cow/day</td>
<td>MG DM/cow/day</td>
<td>protein %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>Supp 3</td>
<td>D</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>kg/cow/day</td>
<td>from A</td>
<td>from B</td>
<td>from B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MG DM/cow/day</td>
<td>MG DM/cow/day</td>
<td>protein %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>E</td>
<td>17</td>
<td>192</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>kg DM/cow/day</td>
<td>A+B+C+D</td>
<td>F+G+H+I</td>
<td>J+K+L+M</td>
</tr>
<tr>
<td></td>
<td>kg/cow</td>
<td>from A</td>
<td>from A</td>
<td>from A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
</tr>
<tr>
<td>Cow req</td>
<td>F</td>
<td>165</td>
<td>16-18</td>
<td>30 %</td>
</tr>
<tr>
<td></td>
<td>MJ</td>
<td>from A</td>
<td>%</td>
<td>NDF</td>
</tr>
</tbody>
</table>

Worksheet 2: The energy, protein and fibre content of a diet (Exercise 11.2)
### Worksheet 2: The energy, protein and fibre content of a diet (Exercise 11.3)

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Silage</th>
<th>Wheat</th>
<th>Supplement 3:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry matter</strong></td>
<td><strong>Energy</strong></td>
<td><strong>Protein</strong></td>
<td><strong>Fibre</strong></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>F</td>
<td>J</td>
</tr>
<tr>
<td>kg DM</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>from A</td>
<td>MJ/kg DM</td>
<td>MJ/ cow/day</td>
<td>protein %</td>
</tr>
<tr>
<td>80</td>
<td>12.0</td>
<td>1.2</td>
<td>56.1</td>
</tr>
<tr>
<td>12.0</td>
<td>100</td>
<td>12.0</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Supplement 1:</strong></td>
<td><strong>Supplement 2:</strong></td>
<td><strong>Supplement 3:</strong></td>
<td><strong>Total</strong></td>
</tr>
<tr>
<td><strong>Silage</strong></td>
<td><strong>Wheat</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.8</td>
<td>89.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>dry matter % from feed test</td>
<td>dry matter % from feed test</td>
<td>dry matter % from feed test</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kg DM/ cow/day</td>
<td>kg DM/ cow/day</td>
<td>kg DM/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>MJ/kg DM</td>
<td>MJ/kg DM</td>
<td>MJ/kg DM</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>12.8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>=</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>MJ/ cow/day</td>
<td>MJ/ cow/day</td>
<td>MJ/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>64</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>=</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>0.6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>protein %</td>
<td>protein %</td>
<td>protein %</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>NDF %</td>
<td>NDF %</td>
<td>NDF %</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td>kg/ cow/day</td>
<td></td>
</tr>
<tr>
<td>from B</td>
<td>from C</td>
<td>from D</td>
<td></td>
</tr>
<tr>
<td>from feed test</td>
<td>from feed test</td>
<td>from feed test</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>kg DM/ cow</td>
<td>kg DM/ cow</td>
<td>kg DM/ cow</td>
<td></td>
</tr>
<tr>
<td>A+B+C+D</td>
<td>E</td>
<td>A+B+C+D</td>
<td></td>
</tr>
<tr>
<td>kg DM/ cow</td>
<td>kg DM/ cow</td>
<td>kg DM/ cow</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>160</td>
<td>2.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Total daily dry matter intake</td>
<td>Total daily energy intake</td>
<td>Total daily protein intake</td>
<td>Total daily fibre intake</td>
</tr>
<tr>
<td>kg/ cow</td>
<td>MJ</td>
<td>kg/ cow</td>
<td>kg/ cow</td>
</tr>
<tr>
<td>16.3</td>
<td>165</td>
<td>16-18</td>
<td>30</td>
</tr>
<tr>
<td>kg/ cow</td>
<td>MJ</td>
<td>%</td>
<td>% NDF</td>
</tr>
</tbody>
</table>
Exercise 11.4: Do the diets meet the cows' requirements?

Compare Worksheet 1 with the two versions of Worksheet 2 to determine whether the diets meet the cows' energy, protein, and fibre requirements. Summarise the information in the table:

<table>
<thead>
<tr>
<th>Situation</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows' requirements (Exercise 11.1)</td>
<td>181</td>
<td>16 – 18</td>
<td>30</td>
</tr>
<tr>
<td>Usual diet (Exercise 11.2)</td>
<td>192</td>
<td>20</td>
<td>24.1</td>
</tr>
<tr>
<td>Poorer-pasture diet (Exercise 11.3)</td>
<td>160</td>
<td>11.8</td>
<td>40.6</td>
</tr>
</tbody>
</table>

Exercise 11.5: Can cows physically eat that much feed?

Calculate the cows' intake limit, using the NDF percentages from Exercises 11.1, 11.2 and 11.3 and either Table 11.2 or the formula relating intake to NDF. Use the following table to compare these limits with the intakes calculated earlier.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Total daily DM intake (kg DM)</th>
<th>Daily DM intake limit (kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual (Exercise 11.2)</td>
<td>17</td>
<td>27.4</td>
</tr>
<tr>
<td>Poorer pasture (Exercise 11.3)</td>
<td>17</td>
<td>16.3</td>
</tr>
</tbody>
</table>
Worksheet 3: The cost of nutrients in feeds
(Exercise 11.6)

Feed 1: Silage

<table>
<thead>
<tr>
<th>Cost per kg DM</th>
<th>Feed 1: Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>460</td>
<td>X</td>
</tr>
<tr>
<td>kg bought (i)</td>
<td>28.8</td>
</tr>
<tr>
<td>kg DM %=</td>
<td>100</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>132.5</td>
<td></td>
</tr>
</tbody>
</table>

Cost of (i) (b) kg DM bought (from A) = 41 ÷ 132.5 X 100 = 30.9

Cost per MJ ME

<table>
<thead>
<tr>
<th>Cost per MJ ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.9</td>
</tr>
</tbody>
</table>

Cost per kilogram crude protein (or NDF)

<table>
<thead>
<tr>
<th>Cost per kilogram crude protein (or NDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.9</td>
</tr>
</tbody>
</table>

Feed 2: Wheat

<table>
<thead>
<tr>
<th>Cost per kg DM</th>
<th>Feed 2: Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>X</td>
</tr>
<tr>
<td>kg bought (i)</td>
<td>89.8</td>
</tr>
<tr>
<td>kg DM %=</td>
<td>100</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>898</td>
<td></td>
</tr>
</tbody>
</table>

Cost of (i) (b) kg DM bought (from A) = 250 ÷ 898 X 100 = 27.8

Cost per MJ ME

<table>
<thead>
<tr>
<th>Cost per MJ ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost per kilogram crude protein (or NDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.8</td>
</tr>
</tbody>
</table>

† To convert dollars per kilogram to cents per kilogram.
Exercise 12.1: How do milk production and body condition change when diet changes?

In all scenarios, the cows have access to plenty of good-quality pasture (24 per cent protein, 30 per cent NDF). Below are some changes that could be made to their diet. Describe how a cow’s milk production (litres, fat test, protein test) and body condition might change, if her diet is changed. (Answer Up, Down or Steady)

<table>
<thead>
<tr>
<th>Diet change</th>
<th>Milk (L)</th>
<th>Fat (kg)</th>
<th>Fat test (%)</th>
<th>Protein (kg)</th>
<th>Protein test (%)</th>
<th>Body condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat fed gradually increases from 1 kg to 4 kg per cow.</td>
<td>Up</td>
<td>Up</td>
<td>Down</td>
<td>Up</td>
<td>Steady</td>
<td>*</td>
</tr>
<tr>
<td>Wheat fed suddenly increases from 1 kg to 6 kg per cow.</td>
<td>Down</td>
<td>Down</td>
<td>Down</td>
<td>Down</td>
<td>Steady or Down</td>
<td>*</td>
</tr>
<tr>
<td>Hay is fed.</td>
<td>Down</td>
<td>Down</td>
<td>Up</td>
<td>Down</td>
<td>Steady or Down</td>
<td>*</td>
</tr>
<tr>
<td>Turnips are fed.</td>
<td>Up</td>
<td>Up</td>
<td>Down</td>
<td>Up</td>
<td>Steady</td>
<td>*</td>
</tr>
</tbody>
</table>

*Depends on stage of lactation.
Exercise 12.2: What is the value of a certain type of milk?

Milk prices are calculated by different methods. The table below lists different daily milk production, with differing tests for fat and protein and with one type of compositional pricing structure.

Calculate the value of each component in the milk to determine which cow's milk has the highest value. Round your answers to the number of decimal places shown for Cow 1; i.e. two decimal places for columns D and J, and three decimal places for columns E, F, G, H, and I.

<table>
<thead>
<tr>
<th>Cow</th>
<th>L</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D (Fat yield (kg))</th>
<th>E (Protein yield (kg))</th>
<th>F (Fat ($)</th>
<th>G (Protein ($)</th>
<th>H (Litre charge ($)</th>
<th>I (Total return ($)</th>
<th>J (Total return ($))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>5.30</td>
<td>4.30</td>
<td>0.81</td>
<td>$1.749</td>
<td>$3.225</td>
<td>$0.420</td>
<td>$4.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>4.50</td>
<td>3.60</td>
<td>0.80</td>
<td>$1.485</td>
<td>$2.700</td>
<td>$0.420</td>
<td>$3.77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>4.17</td>
<td>3.25</td>
<td>0.78</td>
<td>$1.652</td>
<td>$2.925</td>
<td>$0.504</td>
<td>$4.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>4.50</td>
<td>3.60</td>
<td>0.80</td>
<td>$1.782</td>
<td>$3.240</td>
<td>$0.504</td>
<td>$4.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>3.90</td>
<td>3.10</td>
<td>0.79</td>
<td>$1.716</td>
<td>$3.100</td>
<td>$0.560</td>
<td>$4.26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>4.60</td>
<td>3.90</td>
<td>0.85</td>
<td>$2.024</td>
<td>$3.900</td>
<td>$0.560</td>
<td>$5.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>3.60</td>
<td>2.80</td>
<td>0.78</td>
<td>$1.742</td>
<td>$3.080</td>
<td>$0.616</td>
<td>$4.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>4.10</td>
<td>3.30</td>
<td>0.80</td>
<td>$1.984</td>
<td>$3.630</td>
<td>$0.616</td>
<td>$5.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>25</td>
<td>3.70</td>
<td>3.00</td>
<td>0.81</td>
<td>$2.035</td>
<td>$3.750</td>
<td>$0.700</td>
<td>$5.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>25</td>
<td>4.00</td>
<td>3.30</td>
<td>0.83</td>
<td>$2.200</td>
<td>$4.125</td>
<td>$0.700</td>
<td>$5.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>3.70</td>
<td>3.00</td>
<td>0.81</td>
<td>$2.442</td>
<td>$4.500</td>
<td>$0.840</td>
<td>$6.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>3.60</td>
<td>2.90</td>
<td>0.81</td>
<td>$2.376</td>
<td>$4.350</td>
<td>$0.840</td>
<td>$5.89</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Highest value = Cow 11.
Exercise 14.1 Use Worksheet 3 to calculate the cost of nutrients in the calf feeds you use.

Answers depend on the feeds you use on your farm, and how much they cost.
Appendix B: Vitamins and Minerals Required by Dairy Cows

Vitamins required by dairy cows

**Vitamin A**

Vitamin A (retinol) is a component of the visual pigments in the eye. It is also involved in the formation of tissue and bone and is required for growth, milk production and reproduction. Excess vitamin A is stored in the liver for up to 3–4 months.

Vitamin A is formed from dietary carotene in the intestinal wall. Most of the vitamin A requirement is met by the consumption of grasses. Deficiencies of vitamin A are uncommon in grazing cattle but can occur in cattle fed diets high in cereals or cereal straws or in calves fed low fat milk replacers low in vitamin A.

**Vitamin D**

Vitamin D is closely involved with calcium (Ca) and phosphorus (P) metabolism as it is required for Ca and P absorption and deposition within bone. It also stimulates the absorption of calcium from the small intestine. If Ca and P levels are adequate in the diet, the need for vitamin D is small.

Vitamin D is also required for the growth and maintenance of teeth and bone.

Vitamin D is used in the prevention of milk fever. However, the effectiveness of vitamin D in treating milk fever is reduced when dietary calcium is too low or too high. The best results are achieved when calcium intakes are in the order of 50–70g calcium/day.

Vitamin D is formed in the skin following exposure to sunlight and is stored in the liver. Deficiencies are rare, however vitamin D toxicity has been observed in cows given excessive doses of vitamin D during the treatment of milk fever. Vitamin D toxicity results in the calcification of the body's soft tissues (especially the aorta in the heart).


**Vitamin E/Selenium**

A deficiency of either vitamin E or selenium (Se) leads to muscular dystrophy (white muscle disease) which produces stiffness, uncoordinated movement and in severe cases, death from heart failure. Vitamin E prevents damage to cell membranes.

Both vitamin E and Se have anti-oxidant properties that protect biological systems from degradation and may play other key roles in maintaining reproductive health. Research has found that Se accumulates in body tissues important to reproductive health. There is some suggestion that Se deficiency may cause early embryonic loss. Animals deficient in Se and vitamin E may have suppressed defences against infectious diseases.

Cows supplemented with Vitamin E and Se have demonstrated improved conception rate, sperm transport, increased uterine contractions moving towards the oviduct, more robust immune systems (leading to reduced incidence of metritis) and reduced cases of retained foetal membranes and cystic ovaries.

Selenium and vitamin E supplementation is of value in areas deficient in Se when such deficiencies are limiting reproductive performance. Northern Victoria is not deficient in Se and trial work has shown no response to Se supplementation.
## Minerals required by dairy cows

### Macrominerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Interfering factors</th>
<th>Function</th>
<th>Major sources</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>Phosphorus, vitamin D</td>
<td>Component of bone and teeth, involved in heart, muscle and nerve function and blood coagulation. Essential for milk production</td>
<td>Bone reserves mobilised during mild dietary deficiencies, legumes, grasses.</td>
<td>Absorbed from rumen and small intestine at a rate equivalent to the rate needed, regardless of intake. Concentration in milk constant – milk production is the main variable affecting requirement.</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Potassium, high levels of rumen ammonia</td>
<td>Nerve and muscle function, carbohydrate and lipid metabolism, involved in the secretion of some hormones. Plays a role in regulating calcium in blood and bone.</td>
<td>Legumes, grasses, causmag, Epsom salts or magnesium chloride.</td>
<td>Absorbed in rumen and stored in bone. Bone reserves inadequate to meet daily requirements. Excess Mg excreted in the urine. Excess Mg (greater than 60g/day) causes diarrhoea in cattle and inhibits absorption of calcium and phosphorus.</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td></td>
<td>Essential for enzyme, muscle and nerve function. Major role in carbohydrate metabolism and in nerves and muscles.</td>
<td>Grasses, potassium chloride.</td>
<td>Absorbed in intestine, excess K excreted in urine. Excess K reduces absorption of magnesium from rumen, especially when sodium is low.</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td></td>
<td>Na necessary for absorption of sugar and amino acids from the digestive tract. CI plays a role in gastric digestion in the abomasum. Na and CI involved with potassium in osmotic regulation and in acid-base balance.</td>
<td>Pasture generally contains plenty of Na. Salt licks</td>
<td>Na and Cl absorbed from digestive tract. Any excess is secreted in urine. The kidney and the lower gut reduce excretion in urine and faeces when Na and Cl are in short supply.</td>
</tr>
<tr>
<td>Mineral</td>
<td>Interfering factors</td>
<td>Function</td>
<td>Major sources</td>
<td>Notes</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------</td>
<td>----------</td>
<td>---------------</td>
<td>-------</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Molybdenum, zinc, iron, selenium</td>
<td>Required for haemoglobin synthesis and involved in some enzyme and nerve formation. Also required for production of hair pigments and cartilage.</td>
<td>Higher levels in clover.</td>
<td>Absorbed from stomach, small intestine and large intestine. Toxicity uncommon in adults but can affect weight gain in milk fed calves.</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>Vitamin E, iron</td>
<td>Important in microbial enzymes and tissue protein as well as antibody production (and therefore immune function).</td>
<td>Higher levels in grasses than clover. Se bullet.</td>
<td>Absorbed from small intestines. Deficiency in adults linked with retained placenta and muscular weakness after calving. Muscular dystrophy associated with lack of Se or Vitamin E in calves. Toxicity causes death.</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td></td>
<td>Incorporate into the amino acids methionine, cystine and cysteine. Insulin and the vitamins thiamine and biotin also contain sulphur</td>
<td>Deficiency, which is rare, depresses digestion in rumen and food intake. Excess S plus high intake of Mo depresses the availability of Cu.</td>
<td></td>
</tr>
<tr>
<td>Iodine (I)</td>
<td>Manganese, cobalt, calcium, goitrogens</td>
<td>Required for synthesis of thyroid hormones that regulate rate of energy metabolism. Goitrogens found in some clovers inhibit hormone synthesis.</td>
<td>Iodised salt licks.</td>
<td>Absorbed very efficiently from the intestines. Excess I excreted in kidney. Deficiency causes reduced growth rates, reproductive failure and low milk production.</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Calcium, phosphorus, copper, zinc</td>
<td>Major component of haemoglobin which is required for oxygen transport in the blood. Storage forms in muscle. Also required by several enzymes.</td>
<td>Excess Fe harmful to Cu and P metabolism. Blood loss from parasite burdens linked to deficiencies.</td>
<td></td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td></td>
<td>Integral role in several enzymes. Required for bone and cartilage formation and fat and carbohydrate metabolism. It is therefore essential for growth, skeletal development, reproduction.</td>
<td>Found throughout the body. Deficiency has been linked to reduced reproductive performance. Excess manganese interferes with Fe metabolism, depressing blood concentrations of haemoglobin.</td>
<td></td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>Component of vitamin B12 synthesised in rumen. All symptoms of deficiency are associated with a malfunction of enzymes that require vitamin B12.</td>
<td>More in clover than grasses.</td>
<td>B12 enzymes are responsible for propionate use in the liver. Deficiency leads to a loss in weight and milk production. Toxicities rare.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Data Tables

This appendix contains all the data tables that you will need to refer to as you work the exercises and the case study.

Energy needed for maintenance

Table 5.1: Energy requirements for maintenance.

<table>
<thead>
<tr>
<th>Liveweight (kg)</th>
<th>Energy requirement (MJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>17</td>
</tr>
<tr>
<td>150</td>
<td>22</td>
</tr>
<tr>
<td>200</td>
<td>27</td>
</tr>
<tr>
<td>250</td>
<td>31</td>
</tr>
<tr>
<td>300</td>
<td>36</td>
</tr>
<tr>
<td>350</td>
<td>40</td>
</tr>
<tr>
<td>400</td>
<td>Typical Jersey cow range</td>
</tr>
<tr>
<td>450</td>
<td>49</td>
</tr>
<tr>
<td>500</td>
<td>Typical Friesian cow range</td>
</tr>
<tr>
<td>550</td>
<td>54</td>
</tr>
<tr>
<td>600</td>
<td>59</td>
</tr>
<tr>
<td>700</td>
<td>63</td>
</tr>
<tr>
<td>750</td>
<td>72</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)

Energy needed for activity

On flat terrain, 1 MJ per kilometre should be added to provide the energy needed to walk to and from the dairy. On very steep terrain, 5 MJ are required per kilometre. Between these two extremes, include an allowance for activity which reflects the degree of undulation of the terrain.

Energy needed for pregnancy

From conception through the first five months of pregnancy, the additional energy required is approximately 1 MJ ME/day for each month of pregnancy.
Table 5.2 shows the average daily energy requirements during the last four months.

### Table 5.2: Average daily energy requirements in the last four months of pregnancy.

<table>
<thead>
<tr>
<th>Month of pregnancy</th>
<th>Additional energy required (MJ/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sixth</td>
<td>8</td>
</tr>
<tr>
<td>Seventh</td>
<td>10</td>
</tr>
<tr>
<td>Eighth</td>
<td>15</td>
</tr>
<tr>
<td>Ninth</td>
<td>20</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)
Energy needed for milk production

Table 5.3: Energy needed per litre of milk of varying composition.

<table>
<thead>
<tr>
<th>Protein (%)</th>
<th>2.6</th>
<th>2.8</th>
<th>3.0</th>
<th>3.2</th>
<th>3.4</th>
<th>3.6</th>
<th>3.8</th>
<th>4.0</th>
<th>4.2</th>
<th>4.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>4.5</td>
<td>4.5</td>
<td>4.6</td>
<td>4.7</td>
<td>4.8</td>
<td>4.8</td>
<td>4.9</td>
<td>5.0</td>
<td>5.0</td>
<td>5.1</td>
</tr>
<tr>
<td>3.2</td>
<td>4.6</td>
<td>4.7</td>
<td>4.7</td>
<td>4.8</td>
<td>4.9</td>
<td>5.0</td>
<td>5.0</td>
<td>5.1</td>
<td>5.2</td>
<td>5.2</td>
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<tr>
<td>3.4</td>
<td>4.7</td>
<td>4.8</td>
<td>4.9</td>
<td>4.9</td>
<td>5.0</td>
<td>5.1</td>
<td>5.2</td>
<td>5.2</td>
<td>5.3</td>
<td>5.4</td>
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<tr>
<td>3.6</td>
<td>4.9</td>
<td>4.9</td>
<td>5.0</td>
<td>5.1</td>
<td>5.1</td>
<td>5.2</td>
<td>5.3</td>
<td>5.4</td>
<td>5.4</td>
<td>5.5</td>
</tr>
<tr>
<td>3.8</td>
<td>5.0</td>
<td>5.1</td>
<td>5.1</td>
<td>5.2</td>
<td>5.3</td>
<td>5.3</td>
<td>5.4</td>
<td>5.5</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>4.0</td>
<td>5.1</td>
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<td>5.3</td>
<td>5.4</td>
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<td>5.5</td>
<td>5.6</td>
<td>5.7</td>
<td>5.8</td>
</tr>
<tr>
<td>4.2</td>
<td>5.3</td>
<td>5.3</td>
<td>5.4</td>
<td>5.5</td>
<td>5.5</td>
<td>5.6</td>
<td>5.7</td>
<td>5.7</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>4.4</td>
<td>5.4</td>
<td>5.4</td>
<td>5.4</td>
<td>5.5</td>
<td>5.6</td>
<td>5.7</td>
<td>5.7</td>
<td>5.8</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>4.6</td>
<td>5.5</td>
<td>5.6</td>
<td>5.6</td>
<td>5.7</td>
<td>5.7</td>
<td>5.8</td>
<td>5.9</td>
<td>5.9</td>
<td>6.0</td>
<td>6.1</td>
</tr>
<tr>
<td>4.8</td>
<td>5.6</td>
<td>5.7</td>
<td>5.8</td>
<td>5.9</td>
<td>5.9</td>
<td>6.0</td>
<td>6.1</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
</tr>
<tr>
<td>5.0</td>
<td>5.8</td>
<td>5.8</td>
<td>5.9</td>
<td>6.0</td>
<td>6.1</td>
<td>6.1</td>
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<td>6.3</td>
<td>6.4</td>
</tr>
<tr>
<td>5.2</td>
<td>5.9</td>
<td>6.0</td>
<td>6.0</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
<td>6.4</td>
<td>6.4</td>
<td>6.5</td>
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<td>5.4</td>
<td>6.0</td>
<td>6.1</td>
<td>6.2</td>
<td>6.3</td>
<td>6.3</td>
<td>6.4</td>
<td>6.5</td>
<td>6.5</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>5.6</td>
<td>6.2</td>
<td>6.2</td>
<td>6.3</td>
<td>6.4</td>
<td>6.5</td>
<td>6.5</td>
<td>6.6</td>
<td>6.7</td>
<td>6.7</td>
<td>6.8</td>
</tr>
<tr>
<td>5.8</td>
<td>6.3</td>
<td>6.4</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>6.7</td>
<td>6.7</td>
<td>6.8</td>
<td>6.9</td>
<td>6.9</td>
</tr>
<tr>
<td>6.0</td>
<td>6.4</td>
<td>6.5</td>
<td>6.6</td>
<td>6.6</td>
<td>6.7</td>
<td>6.8</td>
<td>6.9</td>
<td>6.9</td>
<td>7.0</td>
<td>7.1</td>
</tr>
</tbody>
</table>

(Source: MAFF, 1984.)

Energy needed for body condition

Table 5.4 shows how much different condition scores weigh. Generally, the amount of weight gain required to increase the cow’s condition by one condition score is about 8 per cent of the cow’s current liveweight.

Table 5.4: The weight of one condition score on cows of different sizes.

<table>
<thead>
<tr>
<th>cow’s approximate liveweight (kg)</th>
<th>Additional weight to increase by one condition score (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>550 (Friesian)</td>
<td>44</td>
</tr>
<tr>
<td>475 (Friesian X Jersey)</td>
<td>38</td>
</tr>
<tr>
<td>400 (Jersey)</td>
<td>32</td>
</tr>
</tbody>
</table>
Table 5.5: The energy a kilogram of body weight or condition needs or releases.

<table>
<thead>
<tr>
<th>Change in body condition</th>
<th>MJ needed to gain 1 kg of weight</th>
<th>MJ available from 1 kg of weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late lactation gain</td>
<td>44</td>
<td>-</td>
</tr>
<tr>
<td>Dry period gain</td>
<td>55</td>
<td>-</td>
</tr>
<tr>
<td>Weight loss</td>
<td>-</td>
<td>28</td>
</tr>
</tbody>
</table>

**Protein requirements**

Table 5.6: Crude protein needs of a cow at different production levels.

<table>
<thead>
<tr>
<th>Milk production</th>
<th>Crude protein requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early lactation</td>
<td>16–18%</td>
</tr>
<tr>
<td>Mid lactation</td>
<td>14–16%</td>
</tr>
<tr>
<td>Late lactation</td>
<td>12–14%</td>
</tr>
<tr>
<td>Dry</td>
<td>10–12%</td>
</tr>
</tbody>
</table>

**Fibre requirements**

Table 5.7: The absolute minimum percentage of fibre needed in a cow’s diet for healthy rumen function (using three different measures of fibre).

<table>
<thead>
<tr>
<th>Fibre measurement</th>
<th>Minimum amount of fibre in the diet (percent of total dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral detergent fibre</td>
<td>30%</td>
</tr>
<tr>
<td>Acid detergent fibre</td>
<td>19%</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>17%</td>
</tr>
</tbody>
</table>
### Calculating the cow’s daily intake limit

**Table 11.2:** Maximum daily intake of cows as affected by the NDF % of the diet.

<table>
<thead>
<tr>
<th>Live-weight (kg)</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4.8</td>
<td>4.0</td>
<td>3.4</td>
<td>3.0</td>
<td>2.7</td>
<td>2.4</td>
<td>2.2</td>
<td>2.0</td>
<td>1.8</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>150</td>
<td>7.2</td>
<td>6.0</td>
<td>5.1</td>
<td>4.5</td>
<td>4.0</td>
<td>3.6</td>
<td>3.3</td>
<td>3.0</td>
<td>2.8</td>
<td>2.6</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>200</td>
<td>9.6</td>
<td>8.0</td>
<td>6.9</td>
<td>6.0</td>
<td>5.3</td>
<td>4.8</td>
<td>4.4</td>
<td>4.0</td>
<td>3.7</td>
<td>3.4</td>
<td>3.2</td>
<td>3.0</td>
</tr>
<tr>
<td>250</td>
<td>12.0</td>
<td>10.0</td>
<td>8.6</td>
<td>7.5</td>
<td>6.7</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.6</td>
<td>4.3</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>300</td>
<td>14.4</td>
<td>12.0</td>
<td>10.3</td>
<td>9.0</td>
<td>8.0</td>
<td>7.2</td>
<td>6.5</td>
<td>6.0</td>
<td>5.5</td>
<td>5.1</td>
<td>4.8</td>
<td>4.5</td>
</tr>
<tr>
<td>350</td>
<td>16.8</td>
<td>14.0</td>
<td>12.0</td>
<td>10.5</td>
<td>9.3</td>
<td>8.4</td>
<td>7.6</td>
<td>7.0</td>
<td>6.5</td>
<td>6.0</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td>400</td>
<td>19.2</td>
<td>16.0</td>
<td>13.7</td>
<td>12.0</td>
<td>10.7</td>
<td>9.6</td>
<td>8.7</td>
<td>8.0</td>
<td>7.4</td>
<td>6.9</td>
<td>6.4</td>
<td>6.0</td>
</tr>
<tr>
<td>450</td>
<td>21.6</td>
<td>18.0</td>
<td>15.4</td>
<td>13.5</td>
<td>12.0</td>
<td>10.8</td>
<td>9.8</td>
<td>9.0</td>
<td>8.3</td>
<td>7.7</td>
<td>7.2</td>
<td>6.8</td>
</tr>
<tr>
<td>500</td>
<td>24.0</td>
<td>20.0</td>
<td>17.1</td>
<td>15.0</td>
<td>13.3</td>
<td>12.0</td>
<td>10.9</td>
<td>10.0</td>
<td>9.2</td>
<td>8.6</td>
<td>8.0</td>
<td>7.5</td>
</tr>
<tr>
<td>550</td>
<td>26.4</td>
<td>22.0</td>
<td>18.9</td>
<td>16.5</td>
<td>14.7</td>
<td>13.2</td>
<td>12.0</td>
<td>11.0</td>
<td>10.2</td>
<td>9.4</td>
<td>8.8</td>
<td>8.3</td>
</tr>
<tr>
<td>600</td>
<td>28.8</td>
<td>24.0</td>
<td>20.6</td>
<td>18.0</td>
<td>16.0</td>
<td>14.4</td>
<td>13.1</td>
<td>12.0</td>
<td>11.1</td>
<td>10.3</td>
<td>9.6</td>
<td>9.0</td>
</tr>
<tr>
<td>650</td>
<td>31.2</td>
<td>26.0</td>
<td>22.3</td>
<td>19.5</td>
<td>17.3</td>
<td>15.6</td>
<td>14.2</td>
<td>13.0</td>
<td>12.0</td>
<td>11.1</td>
<td>10.4</td>
<td>9.8</td>
</tr>
</tbody>
</table>

*Source: Linn and Martin, 1989*

Alternatively, you can use the formula:

\[(120 \div \text{NDF}%) \div 100 \times \text{liveweight} = \text{kg DM/d maximum intake.}\]

For example, if a feed has 37.5% NDF, the maximum intake for a 600-kg cow is:

\[(120 \div 37.5) \div 100 \times 600 = 19.2 \text{ kg DM/d maximum intake.}\]
Note: If ranges are not presented the average value is from a single sample, therefore value should be used with caution.

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM (%)</th>
<th>ME (MJ/kg DM)</th>
<th>CP (%)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
</tr>
<tr>
<td>Almond hulls</td>
<td>90</td>
<td>8.6</td>
<td>7.2–10.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Apple pomace (dried)</td>
<td>89</td>
<td>10.0</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>Barley</td>
<td>90</td>
<td>12.0</td>
<td>12.0–14.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Barley screenings</td>
<td>89</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley straw</td>
<td>85</td>
<td>6.0</td>
<td>5.0–8.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Bean kibble</td>
<td>92</td>
<td>8.7</td>
<td></td>
<td>15.0</td>
</tr>
<tr>
<td>Brewers grain</td>
<td>25</td>
<td>10.0</td>
<td>9.0–12.0</td>
<td>23.0</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>88</td>
<td>11.0</td>
<td></td>
<td>12.0</td>
</tr>
<tr>
<td>Canola meal</td>
<td>85</td>
<td>12.0</td>
<td>11.0–13.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Carrot pulp</td>
<td>14</td>
<td>9.0</td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td>Carrots</td>
<td>13</td>
<td>12.0</td>
<td></td>
<td>10.0</td>
</tr>
<tr>
<td>Chocolate (28% fat)</td>
<td>98</td>
<td>18.2</td>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td>Citrus pulp</td>
<td>19</td>
<td>12.0</td>
<td>10.0–13.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Cornflakes</td>
<td>95</td>
<td>13.2</td>
<td></td>
<td>11.4</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>90</td>
<td>15.0</td>
<td>13.0–16.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Faba bean pollard</td>
<td>90</td>
<td>9.4</td>
<td></td>
<td>16.1</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>85</td>
<td>12.0</td>
<td>10.0–13.0</td>
<td>67.0</td>
</tr>
<tr>
<td>Grape marc</td>
<td>90</td>
<td>4.9</td>
<td>4.0–6.1</td>
<td>12.2</td>
</tr>
<tr>
<td>Linseed meal</td>
<td>85</td>
<td>12.0</td>
<td></td>
<td>34.0</td>
</tr>
<tr>
<td>Lucerne hay/silage</td>
<td>28–80</td>
<td>8.0</td>
<td>7.0–9.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Lupins</td>
<td>90</td>
<td>13.0</td>
<td>12.0–13.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Maize (grain)</td>
<td>90</td>
<td>14.0</td>
<td>12.0–16.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Maize (tassel)</td>
<td>19</td>
<td>10.0</td>
<td></td>
<td>11.0</td>
</tr>
<tr>
<td>Maize silage</td>
<td>35</td>
<td>10.0</td>
<td>9.0–11.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Malt combings</td>
<td>11.0</td>
<td>9.8–12.2</td>
<td></td>
<td>21.4</td>
</tr>
</tbody>
</table>
### Appendix D: Feed Values

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM (%)</th>
<th>ME (MJ/kg DM)</th>
<th>CP (%)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>Millet</td>
<td>18</td>
<td>9.0</td>
<td>11.0</td>
<td>40.0–60.0</td>
</tr>
<tr>
<td>Molasses</td>
<td>77</td>
<td>11.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Oat hulls</td>
<td>93</td>
<td>5.0</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Oaten hay</td>
<td>85</td>
<td>8.0</td>
<td>6.0–10.0</td>
<td>50.0–60.0</td>
</tr>
<tr>
<td>Oaten straw</td>
<td>85</td>
<td>6.0</td>
<td>5.0–7.0</td>
<td>3.0–4.0</td>
</tr>
<tr>
<td>Oats</td>
<td>90</td>
<td>11.0</td>
<td>9.0–13.0</td>
<td>32.0</td>
</tr>
<tr>
<td>Oats (flowering)</td>
<td>23</td>
<td>9.0</td>
<td>8.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Oats (immature)</td>
<td>16</td>
<td>10.0</td>
<td>9.0–12.0</td>
<td>46.0</td>
</tr>
<tr>
<td>Pasture</td>
<td>14</td>
<td>13.0</td>
<td>20.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Pea hay</td>
<td>88</td>
<td>9.0</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Pea pollard</td>
<td>91</td>
<td>8.7</td>
<td>6.5–10.5</td>
<td>11.8–20.8</td>
</tr>
<tr>
<td>Peanut hulls</td>
<td>90</td>
<td>4.0</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>Peanut meal</td>
<td>92</td>
<td>12.0</td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td>Peas</td>
<td>90</td>
<td>13.0</td>
<td>12.0–13.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Pistachio nuts</td>
<td>90</td>
<td>7.1</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>Potato mash</td>
<td>24</td>
<td>14.0</td>
<td>10.8–15.7</td>
<td>12.0</td>
</tr>
<tr>
<td>Rape</td>
<td>14</td>
<td>12.0</td>
<td>20.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Rice straw</td>
<td>85</td>
<td>6.0</td>
<td>4.0</td>
<td>3.0–5.0</td>
</tr>
<tr>
<td>Rye bran</td>
<td>91</td>
<td>9.0</td>
<td>17.0</td>
<td></td>
</tr>
<tr>
<td>Ryegrass (annual)</td>
<td>16</td>
<td>11.0</td>
<td>9.5–11.0</td>
<td>30.0–45.0</td>
</tr>
<tr>
<td>Safflower meal</td>
<td>85</td>
<td>11.0</td>
<td>9.0–12.0</td>
<td>58.0</td>
</tr>
<tr>
<td>Sorghum (grain)</td>
<td>90</td>
<td>11.0</td>
<td>7.0–13.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Sorghum (greenchop)</td>
<td>18</td>
<td>9.0</td>
<td>7.0–11.0</td>
<td>40.0–60.0</td>
</tr>
<tr>
<td>Sorghum silage</td>
<td>35</td>
<td>8.0</td>
<td>7.0–9.0</td>
<td>50.0–60.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>85</td>
<td>13.0</td>
<td>12.0–14.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Sunflower hulls</td>
<td>90.0</td>
<td>5.1</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Sunflower meal</td>
<td>85</td>
<td>10.0</td>
<td>6.0–12.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Sunflower seeds</td>
<td>90</td>
<td>12.0</td>
<td>47.0</td>
<td></td>
</tr>
<tr>
<td>Tomato pulp</td>
<td>28</td>
<td>6.3</td>
<td>4.1–8.1</td>
<td>17.7–22.4</td>
</tr>
<tr>
<td>Triticale</td>
<td>90</td>
<td>13.0</td>
<td>12.0–13.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Turnips, bulb</td>
<td>11</td>
<td>13.0</td>
<td>13.0–14.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Turnips, leaf</td>
<td>9</td>
<td>12.0</td>
<td>4.5–11.0</td>
<td>24.0</td>
</tr>
</tbody>
</table>
## Appendix D: Feed Values

<table>
<thead>
<tr>
<th>Feed</th>
<th>DM (%)</th>
<th>ME (MJ/kg DM)</th>
<th>CP (%)</th>
<th>NDF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Range</td>
<td>Average</td>
<td>Range</td>
</tr>
<tr>
<td>Turnips, whole</td>
<td>10</td>
<td>13.0</td>
<td>11.0–13.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>90</td>
<td>13.0</td>
<td>12.0–14.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>89</td>
<td>10.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat straw</td>
<td>91</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whey</td>
<td>7</td>
<td>14.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix E: Dry Matter Content of Hay and Silage Bales

<table>
<thead>
<tr>
<th>Bale type</th>
<th>Wet weight (kg)</th>
<th>Dry matter (%)</th>
<th>Dry weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x4 round</td>
<td>250</td>
<td>85</td>
<td>215</td>
</tr>
<tr>
<td>5x4 round</td>
<td>350</td>
<td>85</td>
<td>300</td>
</tr>
<tr>
<td>5x6 round</td>
<td>500</td>
<td>85</td>
<td>425</td>
</tr>
<tr>
<td>8x3x3 square</td>
<td>300</td>
<td>85</td>
<td>255</td>
</tr>
<tr>
<td>8x4x3 square</td>
<td>600</td>
<td>85</td>
<td>510</td>
</tr>
<tr>
<td>8x4x4 square</td>
<td>750</td>
<td>85</td>
<td>640</td>
</tr>
<tr>
<td><strong>Silage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x4 round</td>
<td>700</td>
<td>35</td>
<td>245</td>
</tr>
<tr>
<td>1 cubic metre (wilted)</td>
<td>580</td>
<td>30</td>
<td>175</td>
</tr>
<tr>
<td>1 cubic metre (direct cut)</td>
<td>830</td>
<td>18</td>
<td>115</td>
</tr>
<tr>
<td>1 cubic metre maize silage</td>
<td>500</td>
<td>35</td>
<td>175</td>
</tr>
</tbody>
</table>
Appendix F: Copies of Worksheets Used in the Manual

Appendix F contains blank worksheets for your use.
Worksheet 1: The daily energy, protein and fibre needs of a cow

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>A kg</td>
<td>For maintenance (Table 5.1)</td>
<td>I MJ</td>
</tr>
<tr>
<td>Daily activity level</td>
<td>B MJ/km</td>
<td>For activity</td>
<td>J MJ</td>
</tr>
<tr>
<td>Terrain (1-5)</td>
<td>X MJ</td>
<td>from B km</td>
<td>J MJ</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td>D th month</td>
<td>For pregnancy (Table 5.2)</td>
<td>L MJ</td>
</tr>
<tr>
<td>Daily milk production</td>
<td>E litres</td>
<td>For milk production (Table 5.3)</td>
<td>M MJ</td>
</tr>
<tr>
<td>Volume</td>
<td>X %</td>
<td>from E MJ/L</td>
<td>M MJ</td>
</tr>
<tr>
<td>Fat test</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein test</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>H kg/cow/day</td>
<td>For or from condition (Table 5.5)</td>
<td>N MJ</td>
</tr>
<tr>
<td>gain + loss</td>
<td>X MJ/kg</td>
<td>from H</td>
<td>N MJ</td>
</tr>
<tr>
<td>Total daily needs of this cow: Energy</td>
<td>I + J + L + M ± N MJ</td>
<td>Crude protein %</td>
<td>NDF fibre %</td>
</tr>
</tbody>
</table>
## Worksheet 1: The daily energy, protein and fibre needs of a cow

<table>
<thead>
<tr>
<th>The cow</th>
<th>Her energy needs</th>
<th>Her protein needs</th>
<th>Her fibre needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow liveweight</td>
<td>A kg</td>
<td>I MJ</td>
<td>From maintenance (Table 5.1)</td>
</tr>
<tr>
<td>Daily activity level</td>
<td>B MJ/km</td>
<td>J MJ</td>
<td>For activity from B km</td>
</tr>
<tr>
<td>Month of pregnancy</td>
<td>D th month</td>
<td>L MJ</td>
<td>For pregnancy (Table 5.2)</td>
</tr>
<tr>
<td>Daily milk production</td>
<td>E litres</td>
<td>M MJ</td>
<td>For milk production (Table 5.3) from E MJ/L</td>
</tr>
<tr>
<td>Daily change in body condition</td>
<td>H kg/cow/day</td>
<td>N MJ</td>
<td>For or from condition (Table 5.5) from H MJ/kg</td>
</tr>
</tbody>
</table>

### Total daily needs of this cow:

- Energy from A + B + D + E + H = I + J + L + M ± N MJ
- Crude protein from above %
- NDF fibre from above %
### Worksheet 2: The energy, protein and fibre content of a diet

<table>
<thead>
<tr>
<th>Dry matter</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>A</strong></td>
<td><strong>X</strong></td>
<td><strong>F</strong></td>
<td><strong>O</strong></td>
</tr>
<tr>
<td>kg DM/cow/day from A</td>
<td>MJ/kg DM from feed test</td>
<td>protein % from feed test</td>
<td>NDF % from feed test</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td><strong>X</strong></td>
<td><strong>G</strong></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td>kg/cow/day dry matter % from feed test</td>
<td>kg DM/cow/day from B</td>
<td>protein % from feed test</td>
<td>NDF % from feed test</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td><strong>X</strong></td>
<td><strong>H</strong></td>
<td><strong>Q</strong></td>
</tr>
<tr>
<td>kg/cow/day dry matter % from feed test</td>
<td>kg DM/cow/day from C</td>
<td>protein % from feed test</td>
<td>NDF % from feed test</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td><strong>X</strong></td>
<td><strong>I</strong></td>
<td><strong>R</strong></td>
</tr>
<tr>
<td>kg/cow/day dry matter % from feed test</td>
<td>kg DM/cow/day from D</td>
<td>protein % from feed test</td>
<td>NDF % from feed test</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>N</strong></td>
<td><strong>S</strong></td>
</tr>
<tr>
<td>Total daily dry matter intake</td>
<td>Total daily energy intake</td>
<td>Total daily protein intake</td>
<td>Total daily fibre intake</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A+B+C+D kg DM/cow</td>
<td>F+G+H+I MJ/cow</td>
<td>J+K+L+M kg/cow</td>
<td>O+P+Q+R kg/cow</td>
</tr>
<tr>
<td><strong>Total daily DM intake limit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use T and Table 11.2 or the formula (120 ÷ T) ÷ 100 X liveweight kg/cow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cow requirements</strong> (from Worksheet 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total daily energy requirement</td>
<td>Crude protein requirement</td>
<td>Fibre requirement</td>
<td></td>
</tr>
<tr>
<td>MJ</td>
<td>%</td>
<td>% NDF</td>
<td></td>
</tr>
</tbody>
</table>
Worksheet 2: The energy, protein and fibre content of a diet

<table>
<thead>
<tr>
<th>Dry matter</th>
<th>Energy</th>
<th>Protein</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pasture</strong></td>
<td>A kg DM/cow/day from A</td>
<td>X MJ/kg DM</td>
<td>X protein % from feed test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= F</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplement 1:</strong></td>
<td>B kg/cow/day dry matter % from feed test</td>
<td>C MJ/kg DM</td>
<td>D protein % from feed test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= E</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplement 2:</strong></td>
<td>F kg/cow/day dry matter % from feed test</td>
<td>G MJ/kg DM</td>
<td>H protein % from feed test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= J</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supplement 3:</strong></td>
<td>I kg/cow/day dry matter % from feed test</td>
<td>K MJ/kg DM</td>
<td>L protein % from feed test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>= M</td>
<td>=</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total**

- Total daily dry matter intake: A+B+C+D kg DM/cow
- Total daily energy intake: F+G+H+I MJ/cow
- Total daily protein intake: J+K+L+M kg/cow
- Total daily fibre intake: O+P+Q+R kg/cow

**Cow requirements**

- Total daily energy requirement: MJ
- Crude protein requirement: %
- Fibre requirement: % NDF

Use T and Table 11.2 or the formula 
\[ \text{Total daily DM intake limit} = \frac{120}{T} \times \frac{100}{\text{liveweight}} \]
Worksheet 3: The cost of nutrients in feeds

**Feed 1:**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{\text{Cost per kg DM}}{100} \times \text{DM %} = \text{A}$</td>
<td>Cost per kg DM divided by 100 and multiplied by DM % to find kg DM bought.</td>
</tr>
<tr>
<td>$\frac{\text{Cost of (i) (S)}}{\text{kg DM bought (from A)}} \times 100 \dagger = \text{c/kg DM}$</td>
<td>Cost of (i) (S) divided by kg DM bought (from A) and multiplied by 100 to find c/kg DM.</td>
</tr>
<tr>
<td>$\frac{\text{Cost per MJ ME}}{\text{MJ ME/\text{kg DM}} = \text{C}}$</td>
<td>Cost per MJ ME divided by MJ ME/kg DM to find c/MJ ME.</td>
</tr>
<tr>
<td>$\frac{\text{Cost per kilogram crude protein (or NDF)}}{\text{CP % (or NDF %)} \times 100 = \text{D}}$</td>
<td>Cost per kilogram crude protein (or NDF) divided by CP % (or NDF %) and multiplied by 100 to find c/kg CP (or c/kg NDF).</td>
</tr>
</tbody>
</table>

**Feed 2:**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{\text{Cost per kg DM}}{100} \times \text{DM %} = \text{A}$</td>
<td>Cost per kg DM divided by 100 and multiplied by DM % to find kg DM bought.</td>
</tr>
<tr>
<td>$\frac{\text{Cost of (i) (S)}}{\text{kg DM bought (from A)}} \times 100 \dagger = \text{c/kg DM}$</td>
<td>Cost of (i) (S) divided by kg DM bought (from A) and multiplied by 100 to find c/kg DM.</td>
</tr>
<tr>
<td>$\frac{\text{Cost per MJ ME}}{\text{MJ ME/\text{kg DM}} = \text{C}}$</td>
<td>Cost per MJ ME divided by MJ ME/kg DM to find c/MJ ME.</td>
</tr>
<tr>
<td>$\frac{\text{Cost per kilogram crude protein (or NDF)}}{\text{CP % (or NDF %)} \times 100 = \text{D}}$</td>
<td>Cost per kilogram crude protein (or NDF) divided by CP % (or NDF %) and multiplied by 100 to find c/kg CP (or c/kg NDF).</td>
</tr>
</tbody>
</table>

†To convert dollars per kilogram to cents per kilogram.
## Worksheet 3: The cost of nutrients in feeds

### Feed 1:

| |  
|---|---|
| **Cost per kg DM** | \( \frac{\text{Cost per kg DM}}{100} \times \frac{\text{DM} \%}{\text{kg bought (i)}} \) = \( \frac{\text{DM} \%}{\text{kg DM bought}} \)  
| | A  
| **Cost of (i) ($)** | \( \frac{\text{Cost of (i) ($)}}{\text{kg DM bought from A}} \) = \( \frac{\text{c/kg DM}}{\text{kg DM bought}} \)  
| | B  
| **Cost per MJ ME** | \( \frac{\text{c/kg DM (from B)}}{\text{MJ ME /kg DM}} \) = \( \frac{\text{c/MJ ME}}{\text{MJ ME /kg DM}} \)  
| | C  
| **Cost per kilogram crude protein (or NDF)** | \( \frac{\text{c/kg DM (from B)}}{\text{CP \% (or NDF \%)}} \times 100 \) = \( \frac{\text{c/kg CP (or c/kg NDF)}}{\text{CP \% (or NDF \%)}} \)  
| | D  

### Feed 2:

| |  
|---|---|
| **Cost per kg DM** | \( \frac{\text{Cost per kg DM}}{100} \times \frac{\text{DM} \%}{\text{kg bought (i)}} \) = \( \frac{\text{DM} \%}{\text{kg DM bought}} \)  
| | A  
| **Cost of (i) ($)** | \( \frac{\text{Cost of (i) ($)}}{\text{kg DM bought from A}} \) = \( \frac{\text{c/kg DM}}{\text{kg DM bought}} \)  
| | B  
| **Cost per MJ ME** | \( \frac{\text{c/kg DM (from B)}}{\text{MJ ME /kg DM}} \) = \( \frac{\text{c/MJ ME}}{\text{MJ ME /kg DM}} \)  
| | C  
| **Cost per kilogram crude protein (or NDF)** | \( \frac{\text{c/kg DM (from B)}}{\text{CP \% (or NDF \%)}} \times 100 \) = \( \frac{\text{c/kg CP (or c/kg NDF)}}{\text{CP \% (or NDF \%)}} \)  
| | D  

†To convert dollars per kilogram to cents per kilogram.
Glossary and Abbreviations

Terms in this glossary are defined in the context of their use in this manual.

% CP  the proportion of the dry matter in a feed that is crude protein.

% digestibility  the proportion of the dry matter in a feed that will provide digestible energy. Also PER CENT digestible DM.

% DM  the proportion of dry matter in a feed.

% moisture  the proportion of water in a feed.

% NDF  the proportion of the dry matter in a feed that is neutral detergent fibre.

% RDP  the proportion of a feed’s crude protein that is rumen degradable rather than undegradable.

/  per.

°C  degrees Celsius.

A  acetate  a product of rumen digestion, produced in the main by cellulose-digesting bacteria; important in the production of milk fat. Also acetic acid.

acetic acid  See acetate.

acid detergent fibre  the less digestible or indigestible parts of the fibre; ie., the cellulose and lignin only.

acidosis  an excessive increase in rumen acid caused by feeding too much grain or other starchy feeds or by introducing them into the diet too quickly.

ADF  acid detergent fibre.

amino acid  the building block of proteins; a cow requires 25 different amino
acids for normal metabolic functioning.

as-fed
feed with its moisture still in it. See also dry matter.

B

bites/min
bites per minute.

body condition
energy stored by cows as fat.

buffer
body fluid (e.g., saliva) or feed additive that reduces the acidity in the rumen.

butyrate
a product of rumen digestion of lesser importance in milk production than acetate and propionate.

butyric acid
See butyrate.

bypass protein
See undegradable dietary protein.

C

c
cent(s).

c/g CP
cent(s) per gram of crude protein.

c/g NDF
cent(s) per gram of neutral detergent fibre.

c/kg DM
cent(s) per kilogram of dry matter.

c/MJ ME
cent(s) per megajoule of metabolisable energy.

Ca
calcium.

carbohydrates
the main source of energy in a cow’s diet.

carnivore
meat eater.

casein
milk protein.

cellulose-digesting bacteria
type of rumen microbe that can be eliminated or severely slowed in growth rate by high-fat diets or high acidity in the rumen.

Cl
chloride.

cm
centimetre.

Co
cobalt.

conception rate
the proportion of the total number of services or inseminations that result in pregnancy.
Glossary and Abbreviations

condition
See body condition or condition score.

condition score
objective visual assessment of a cow’s body condition on a scale of 1 (emaciated) to 8 (obese).

CP
crude protein.

crude fibre
a measure of fibre in the diet now considered unacceptable as it does not always take into account all of the constituents that make up the fibre component of a feed; it measures only the alkali-soluble lignin and the cellulose.

crude protein
a rough measure of all the protein in the diet (NPN + RDP + UDP); it assumes (incorrectly) that all the nitrogen in a feed comes from protein.

Cu

copper.

D
day.

DDM
digestible dry matter.

DE
digestible energy.

digestibility
the proportion of the dry matter in a feed that gets digested; it is the difference between what is eaten and what comes out as manure.

digestible energy
energy that is actually absorbed by the cow. See also metabolisable energy.

DM
dry matter.

DM/ha
dry matter per hectare.

DM/ha/d
dry matter per hectare per day.

DNRE
Department of Natural Resources and Environment.

dry matter
the proportion of any feed remaining after all the water has been taken out.

E
energy
the part of a feed that is used as ‘fuel’ in carrying out the cow’s bodily functions.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>energy-dense</td>
<td>having a large amount of metabolisable energy per kilogram of dry matter.</td>
</tr>
<tr>
<td>enzyme</td>
<td>a substance produced by the cow that helps digestion.</td>
</tr>
<tr>
<td>eructation</td>
<td>the belching of gases produced in the rumen during carbohydrate fermentation.</td>
</tr>
<tr>
<td>essential amino acid</td>
<td>any of the 10 amino acids that the cow cannot make herself and therefore must be supplied from the diet or from the products of digestion.</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>iron.</td>
</tr>
<tr>
<td>fibre</td>
<td>the cell wall, or structural material, in a plant made up of (among other things) cellulose, hemicellulose, and lignin.</td>
</tr>
<tr>
<td><strong>G</strong></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>gram(s).</td>
</tr>
<tr>
<td>g/d</td>
<td>gram(s) per day.</td>
</tr>
<tr>
<td>g/kg</td>
<td>gram(s) per kilogram.</td>
</tr>
<tr>
<td>g/kg DM</td>
<td>gram(s) per kilogram of dry matter.</td>
</tr>
<tr>
<td>g/kg LWG/d</td>
<td>gram(s) per kilogram of liveweight gain per day.</td>
</tr>
<tr>
<td>g/kg LWt</td>
<td>gram(s) per kilogram of liveweight.</td>
</tr>
<tr>
<td>g/L</td>
<td>gram(s) per litre.</td>
</tr>
<tr>
<td><strong>H</strong></td>
<td></td>
</tr>
<tr>
<td>ha</td>
<td>hectare(s).</td>
</tr>
<tr>
<td>ha/d</td>
<td>hectare(s) per day.</td>
</tr>
<tr>
<td>hemicellulose</td>
<td>the most digestible part of fibre; included in NDF analyses but not in ADF or CF analyses.</td>
</tr>
<tr>
<td>herbivore</td>
<td>plant eater.</td>
</tr>
<tr>
<td>hormone</td>
<td>a chemical produced by the cow that regulates body functions.</td>
</tr>
</tbody>
</table>
### Glossary and Abbreviations

**I**
- **I**
  - iodine.
- **international units**
  - the unit of measure used for vitamins.
- **IU**
  - international unit(s).

**J**
- **joule**
  - a unit of energy; one calorie equals a bit more than 4,000 joules.

**K**
- **K**
  - potassium.
- **kg**
  - kilogram(s).
- **kg/bite**
  - kilogram(s) per bite.
- **kg DM**
  - kilogram(s) of dry matter.
- **kg DM/ha**
  - kilogram(s) of dry matter per hectare.
- **kg DM/ha/d**
  - kilogram(s) of dry matter per hectare per day.
- **km**
  - kilometre(s).

**L**
- **L**
  - litre(s).
- **L/d**
  - litre(s) per day.
- **lignin**
  - an indigestible part of plant fibre.
- **liveweight**
  - weight of live cow, measured in kilograms.
- **LWG**
  - liveweight gain.
- **LWt**
  - liveweight.

**M**
- **maintenance requirement**
  - the energy needed for essential body functions, such as blood circulation, breathing, keeping warm or cool, digestion, and tissue repair.
- **mastication**
  - chewing.
- **MD**
  - See MJ ME/kg DM.
- **ME**
  - metabolisable energy.
- **megajoule**
  - millions of joules.
metabolic activities for an adult cow, maintenance, milk production, activity, pregnancy, and weight gain; for an immature cow, also growth.

metabolisable energy the amount of energy provided by a feed after deducting energy lost to faeces, urine, heat, and gas production; it is the energy available to be used by the cow for her metabolic activities. See also digestible energy.

metabolism a general term for all chemical activities of living organisms; it includes respiration, fermentation, and repair of body tissues. See also metabolic activities.

Mg magnesium.

mg milligram(s).

mg/kg milligram(s) per kilogram.

mg/kg DM milligram(s) per kilogram of dry matter.

mins/day minutes per day.

MJ megajoule(s).

MJ ME/kg DM megajoules of metabolisable energy per kilogram of dry matter.

mm millimetre.

Mn manganese.

Mo molybdenum.

N nitrogen.

Na sodium.

NDF neutral detergent fibre.

neutral detergent fibre a measure of all the fibre (hemicellulose, lignin, and cellulose) in a feed; it indicates how bulky the feed is.

NH3 ammonia.

non-protein nitrogen not actually protein but simple nitrogen; however, microbes can make protein from simple nitrogen if enough energy (carbohydrates) is available in the rumen at the same time.
Glossary and Abbreviations

NPN  non-protein nitrogen.

O

oxalate  a chemical found in plants of the Oxalis genus (e.g., sourso or wood sorrel).

P

P  phosphorus.

partitioning  the metabolic division of energy intake (above the maintenance requirement) between liveweight gain and milk production.

per  in each or for each.

per cent  in or for each one hundred; for example, 5 per cent means 5 in (or for) each 100: if the interest rate on a loan is 5 per cent a year, you pay $5 a year for each $100 not yet repaid, or if the dry matter per kilogram is 5 per cent, then 50 grams in each kilogram (1,000 grams) is dry matter.

percentage  the rate or proportion per hundred.

pH  a measure of acidity or alkalinity on a scale from 1 (extremely acid) to 14 (extremely alkaline).

ppm  parts per million; equivalent to milligrams per kilogram.

propionate  a product of rumen digestion, produced in the main by starch-digesting and glucose-digesting bacteria; important in milk volume and milk protein production. Also propionic acid.

propionic acid  See propionate.

protein  the material that makes up most of the cows body (muscles, skin, organs, blood); it also is part of milk.

Q

quality  in relationship to feeds, an indication of the level of energy and digestibility.
Glossary and Abbreviations

**R**

RDP  rumen degradable protein.
rumen degradable protein  the portion of protein in the diet that is digested and used by the microbes in the rumen to build themselves, if enough energy (carbohydrates) is available at the same time.
rumen modifier  a product that changes the rumen conditions and/or microbes and thereby changes the fermentation process and the products of fermentation.
rumen undegradable protein  See undegradable dietary protein.
ruminition  regurgitation and chewing of the cud.

**S**

S  sulphur.
Se  selenium.
soluble carbohydrates  include the sugars and simple carbohydrates, which are quickly dissolved and digested in the rumen, produce mainly propionate, are non-fibrous, and are found within the plant cell.
storage carbohydrates  include starch, are quickly dissolved and digested in the rumen, produce mainly acetate, are non-fibrous, and are found within the plant cell.
structural carbohydrates  include lignin, hemicellulose, and cellulose; are dissolved and digested slowly (if at all) in the rumen; are fibrous; and are found in the cell wall.
submission rate  the proportion of the herd inseminated at least once in a given period of time (e.g. the first 10, 21, 24 or 30 days of mating).
substitution  the extent to which a supplement replaces pasture in the diet.
supplement  a feed or product added to the cow’s diet to increase or decrease some dietary component, such as energy, protein, fibre, vitamins, or minerals.
<table>
<thead>
<tr>
<th><strong>T</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>something most of us have too little of.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>U</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UDP</td>
<td>undegradable dietary protein.</td>
</tr>
<tr>
<td>undegradable dietary protein</td>
<td>any protein in the diet that passes through the rumen without breaking down and is digested in the abomasum and small intestine. Also bypass protein.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>V</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VFA</td>
<td>volatile fatty acid.</td>
</tr>
<tr>
<td>volatile fatty acids</td>
<td>the general term for the products of rumen fermentation; the most important of these acids are acetic, propionic, and butyric acids, which are major energy sources for the cow.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Z</strong></th>
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<tbody>
<tr>
<td>Zn</td>
<td>zinc.</td>
</tr>
</tbody>
</table>
Glossary and Abbreviations
References and Suggested Further Reading


