MEAT & LIVESTOCK AUSTRALIA

Going into Goats

Module 7

Edition 2: Updated October 2018

Nutrition

Contents

Introduction

These guidelines were developed by ruminant nutritionists with extensive experience with the Australian goat industry. The aim is to encourage best practice goat production and help ensure the continued growth of the industry.

Estimating the nutritional requirements of goats if the production objective is understood is a relatively simple task; however, in the field this will always only be an estimate due to the number of variables involved. Such variables include:

- feed quality and intake
- availability of native and improved pastures, as well as browse
- breed and productive capacity of the goat (milk, fibre, meat)
- physiological state of the goat (growth, pregnant, lactating, etc)
- degree of activity or exertion.

This module provides a practical approach to estimating the nutritional requirements of goats with different production requirements in a range of environments.

It has been demonstrated that goats outperform other domesticated ruminants in harsh environments, as they are able to adapt better than most other species and have evolved to digest high-fibre, low-nitrogen dietsefficiently. The physiological basis for their superior digestive capacity relates to their ability to recycle nitrogen and their more efficient use of water. While goats are able to take advantage of highly digestible grass, given the opportunity they still maintain intake of 'browse' sufficiently to preserve their acclimatisation to tannin-rich food. Consequently, during drought and hard times when quality pasture is scarce, the animals that suffer least are ruminant browsers like goats and camels and non-ruminants like donkeys. This makes them particularly suited to much of Australia's grazing lands.

What to do?

◆ Goat nutrient requirements

- Different goats have different nutrient requirements – understand the requirements of the goats you are managing.
- Goat requirements vary throughout the year – understand how these requirements vary throughout the year.
- Ruminants have specific requirements – understand the basics of rumen function.

- Feed value
  - Different feeds have different nutrition values – understand the value of the feed your goats are eating and how feeds are broken down by ruminants.
  - Feed volumes and values vary throughout the year – understand the normal fluctuations in feed on offer in your area.
- Economic sustainability
  - Efficiently matching feed supply and demand is a key to profitability – maximise efficiency based on available resources.
  - Optimising stocking rate will maximise productive potential – understand fluctuations in feed supply and demand to maximise productivity.
  - Understanding animal requirements allows feed alternatives to be compared – choose feeds that economically meet the requirements of the animals.

How to do it?

In order to apply the basics of nutritional management in goats, it is important to understand the following:

- basic digestive anatomy and function of the rumen
- fundamental components found in all feeds such as carbohydrates, fat, protein, minerals and vitamins
- daily requirements for energy, protein, minerals and vitamins for varying levels of production and for a range of breeds
- common feeds and supplements available to feed and a process to evaluate the economic returns
- guidelines and hints for implementing various rations
- the nutrient value and management of native pastures.

This module provides an overview of each of these topics to help develop a practical understanding of the key nutritional considerations in Australian goat farming enterprises.

Basic digestive anatomy and function of the rumen

What is a ruminant?

Ruminants are mammals that have a specialist digestive system which enables them to digest high-fibre diets such as grass. They have four compartments to their digestive system – the rumen, reticulum, omasum and abomasum. These are often referenced as the four 'stomach chambers' of a ruminant animal.

The majority of feed available to grazing animals is high in fibre. That is, the feed contains complex structural carbohydrates such as cellulose, which are relatively indigestible.

The ruminant digestive system makes use of fibre-digesting microorganisms, the majority of which live in the rumen and reticulum and are more efficient at converting grass into meat and fibre than 'simple stomach' (monogastric) animals.

However, the ruminant digestive system is less efficient than monogastric systems at digesting high-energy diets, such as grain.

- Ruminants have three cellulose digestion chambers before the digesta reaches the 'true stomach' (abomasum) and each does a different job. This anatomy is different to monogastric animals such as pigs and horses, where food passes directly from the mouth via the oesophagus to the stomach.
- The rumen is the largest of these chambers and develops as a kid grows. It is fully functional by about 8–10 weeks of age.
- Feed intake is the key to performance and is limited by the processing capacity of the rumen.
- Balancing the nutrient requirements of both the rumen microorganisms and the animal is essential for good animal performance.

The main components of the ruminant digestive system are shown in Figure 1 below:

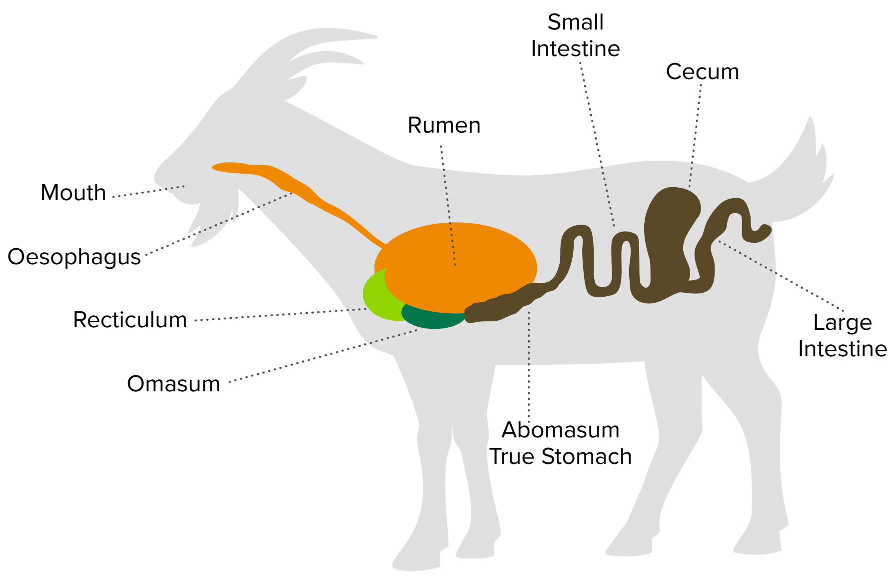


Figure 1: Digestive system of a goat

Mouth

The breakdown of feed begins in the mouth. Goats briefly chew the feed to 1–5cm lengths while adding large amounts of saliva, and then swallow it via the oesophagus into the rumen.

The amount of saliva produced is related to the type of diet, especially the fibre content. Much of this saliva is absorbed as water and recycled. The saliva contains significant quantities of various salts such as phosphorus, bicarbonate and urea. Bicarbonate is essential in maintaining rumen pH at desirable levels to begin the process of digestion. It is essential to maintain adequate fibre in grain-based diets to avoid acidosis and rumen pH must be >6.0.

The rumen pH is commonly around 6.5–7 on pasture diets. The pH of the rumen can be predicted from the per centage of eNDF (effective neutral detergent fibre) in the diet.

Effective neutral detergent fibre (eNDF) is the per centage of NDF effective in stimulating chewing and salivation, rumination and rumen motility. The basic eNDF is determined in a nutrition laboratory and is described as the per cent of NDF remaining on a 1.18mm screen after dry sieving.

When eNDF = 24.5%, then:

> **pH of rumen** = **5.425** + **(0.04229 X eNDF**)
> pH of rumen = **5.425** + **(0.04229 X 24.5**)
> **pH of rumen** = 6.46
> NB: eNDF must be >14 in all complete rations.

Microorganisms found in the rumen further break down the food particles.

If the animal has satisfied its hunger it will ruminate (chew its cud), further decreasing the size of the pieces to increase the surface area of the food for microbial digestion.

Oesophagus

Food is transferred to the stomach via the oesophagus, where muscular contractions propel chewed feed towards the rumen. The oesophagus also moves digesta (cud) from the rumen back to the mouth where it is further ground by chewing to make it easier to digest. Chewing stimulates saliva production and ensures adequate bicarbonate is produced.

◆ Rumen and reticulum

The first two compartments, the rumen and reticulum, act as fermentation vats where plant material is broken down by millions of microorganisms. The oesophagus opens from the mouth into the reticulum. Food not digested in the rumen, as well as rumen microbes, pass through the omasal orifice located in the reticulum, into the omasum.

Between 60 and 70% of all digestion happens in the rumen. Fibre is broken down and much of the protein eaten is converted to microbial protein. The rumen is also where carbohydrates are fermented to volatile fatty acids, which are then absorbed across the rumen wall where they enter the blood stream and are converted in the body to glucose and fat.

At birth, the rumen of kids is very small and doesn't function. It develops quickly so that, by about eight weeks of age, its rumen can break down plant material.

◆ Oesophageal groove

The reticulum also contains the oesophageal groove, an extremely important organ for kids that are suckling.

The oesophageal groove is comprised of two lips that close in response to nervous stimulation during suckling, and forms a tube which diverts milk from the oesophagus to the abomasum. If the oesophageal groove doesn't close, the milk flows into the rumen where it ferments and can cause bloat. This can happen when young ruminants drink milk directly from a bucket. The milk is more efficiently used if it is not fermented in the rumen.

Before weaning, most of the animal's nutrients are supplied from milk (a nutrient-rich food) that is digested in the abomasum. After weaning, the rumen grows quickly to accommodate a high-fibre diet which is much less nutritious than milk.

Table 1: Development of the rumen from birth to maturity

Age of animal	% of total stomach mass		
	Rumen and reticulum	Omasum	Abomasum
At birth	35	14	51
Mature	62	20	18

Originally it was thought that giving young ruminant animals hay resulted in the 'scratch effect' needed to develop the rumen. The rumen develops and starts functioning as a result of volatile fatty acids in the rumen, so it is a chemical effect rather than a physical effect. Providing hay promotes the growth of the muscular layer of the rumen and it maintains the health of the epithelium. The scratch effect of hay prevents the papillae from forming layers of keratin, which would inhibit volatile fatty acids from being absorbed.

Rumination

Rumination is the process where food material is regurgitated into the mouth and further chewing/grinding is performed to break down fibre. In addition, copious amounts of saliva are added to the digesta and this plays an important role in buffering and maintaining the pH of the rumen before swallowing occurs once more.

◆ Rumen microorganisms

The rumen has vast numbers of microorganisms (bacteria, protozoa and fungi) living in it, with bacteria being the most numerous. In rumen fluid, there can be 1–10 billion bacteria per millilitre, 10,000–1,000,000 protozoa and smaller, variable amounts of fungi. These microorganisms grow rapidly with three to four generations possible each day. The numbers and types vary with the diet.

Protozoa can make up to 50% of the microbiological mass in the rumen and are about 40 times the size of bacteria. They eat bacteria and plant matter, especially starch, sugars and protein.

Fungi make up 8% of the microbial mass. They break down very fibrous material making it more accessible to bacteria. They reproduce slowly and their numbers increase when the pasture grazed becomes more fibrous and less digestible.

To function properly, microorganisms need rumen conditions to remain within a specific, limited range. The rumen fluid should be slightly acid (pH 6.5 to 7.0) and there should be a plentiful supply of ammonia and carbohydrates to feed the microbial population. The microbes also require an anaerobic (oxygen-free) environment.

The type of feed the animal eats influences these factors. For example, mature dry grasses are low in protein and simple (easily digestible) carbohydrates, thereby limiting microbial growth. Conversely, high-grain diets can lead to high acidity (low pH) that is toxic to many rumen microorganisms and will also inhibit microbial growth and digestion. Starch-digesting microbes prefer a pH of 5.5–7.0, while fibre-digesting microbes prefer a pH of 6.2–7.0. When the pH drops below 5.5, acidosis occurs.

Fibre-digesting bacteria (or cellulolytic bacteria) are very sensitive to rumen pH. Once the pH drops below 6, the fibre-digesting bacteria don't function well. The reproductive rate of fibre-digesting bacteria is slower than for starch digesters.

Table 2: Bacteria groups according to substrate fermented

Bacteria group	Substrate fermented
Cellulolytic	Plant fibre (cellulose)
Pectinolytic	Plant fibre (pectins)
Hemicelluloytic	Plant fibre but not cellulose (xylans)
Amylolytic	Starch utilising
Ureolytic	Urea utilising
Proteolytic	Protein utilising

Source: pers comm. Athol Klieve

Methane is produced by methanogens, microbes that look similar to bacteria but are actually from a completely separate domain of life – the Archaea. Microbes attach to feed particles and release enzymes.

A typical gas mixture in the rumen is:

- 65% – carbon dioxide
- 27% – methane
- 7% – nitrogen
- 0.6% – oxygen
- 0.2% – hydrogen
- 0.01% – hydrogen sulphide.

Cellulose-digesting bacteria prefer ammonia as their nitrogen source. **It takes 4–6 weeks for the rumen microbes to adapt to a new diet.**

Acidosis

When the rumen pH is low because of large quantities of starch and sugar being fed, *Streptococcus bovis* predominates in the rumen. This bacterium produces lactic acid, which is a stronger acid than many of the other volatile fatty acids produced in the rumen. When conditions are favourable, *Streptococcus bovis* grows extremely rapidly, doubling in numbers every 13 minutes. This causes acidosis. Feeding ionophores (feed additives) such as monensin to feedlot goats improves their growth, as it reduces *Streptococcus bovis* numbers. Monensin **should not be fed to young pre-ruminant animals**.

◆ Acidosis in young ruminants

Young ruminants are very susceptible to rumen acidity, when the pH drops to 5 or lower. This is caused by:

1. reflux of abomasal fluids into the rumen (fed too much at one meal)
2. bacterial fermentation of liquid in the developing rumen.

This results in a build-up of volatile fatty acids and lactic acid.

To prevent acidosis in kids:

1. have regular feeding times
2. provide good quality milk replacer
3. ensure milk isn't too cold when feeding
4. avoid bucket-feeding where possible
5. minimise stress, such as long-distance transport
6. don't feed green grass or lucerne to very young kids as it can cause bloat when the rumen is not fully developed – provide a small amount of roughage hay/chaff.

◆ Ideal rumen environment

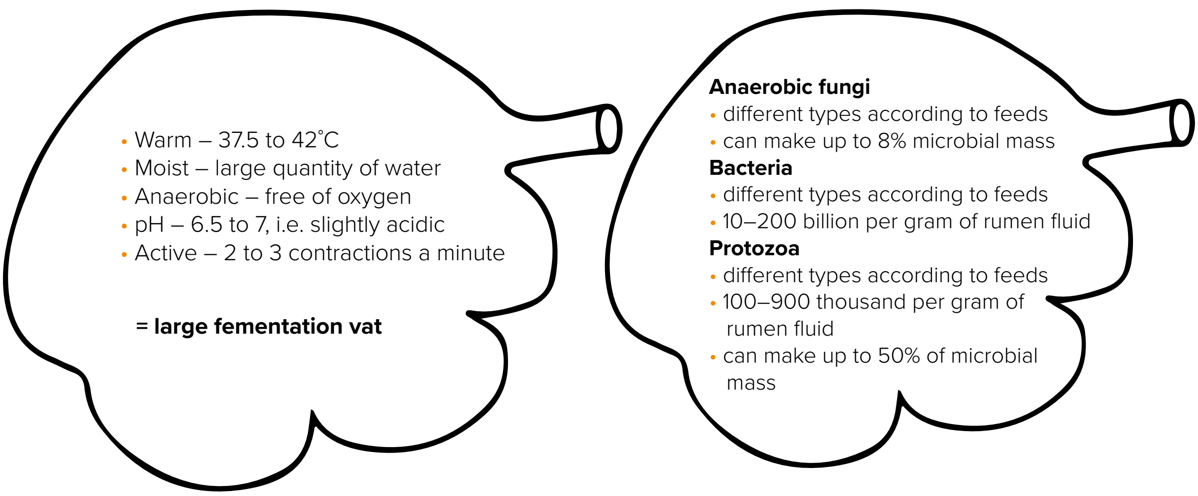


Figure 2: Types of rumen microorganisms

The grazing animal provides the home (the rumen) for microorganisms and harvests the forage. The microbes digest the forage to supply the nutrients for their own growth and reproduction. Nutrients that the microbes don't use, and the microbes themselves, supply the nutrients for the animal's growth and reproduction. The rumen microbes require a certain amount of energy and nitrogen to operate efficiently. Non-protein nitrogen such as urea can be used to ensure the rumen operates to its maximum level of efficiency in animals with a functional rumen. The rumen microbes then pass into the intestines and provide most of the protein requirements for the animal, except in young and high-milk-producing animals.

Omasum

The detailed function of the omasum is not well understood. It appears to be involved in reducing the amount of water passing out of the rumen with the partially digested plant material, in further grinding the food and in squeezing the digesta through to the abomasum.

Abomasum

The abomasum is the true, gastric stomach of the animal, similar in function to the stomach of monogastrics (e.g. pigs and people). Protein and some fats are digested in the abomasum with the aid of hydrochloric acid and enzymes.

Small intestine

The small intestine is the main site for the digestion and absorption of amino acids, fats and the limited amount of glucose that may be available. The small intestine is also the main site for absorption of phosphorus. The bile and pancreatic ducts open into the small intestine, delivering enzymes, solvents, buffers and other agents (such as sodium bicarbonate) to aid digestion.

Large intestine

The large intestine consists of the caecum, colon, rectum and anus. Some breakdown of feed by microorganisms takes place in the large intestine but the products are generally not absorbed here. The primary role of the large intestine in ruminants is to absorb water and to collect waste material from digestion before defecation.

Nutrients

Grazing animals get their nutrients from pasture and supplements and then convert these nutrients into bone, muscle and fat.

Nutrients are:

- carbohydrates
- fat
- protein
- minerals
- vitamins.

Plants are made up of:

- water
- carbohydrates
  - structural (e.g. cellulose and hemicellulose)
  - non-structural (e.g. simple sugars and starches)
- protein
- minerals
- lipids.

These plant components are broken down to produce:

- volatile fatty acids (main ones)
  - acetic
  - propionic
  - butyric
- microbial protein
  - long-chain fatty acids
- glucose.

Terms used:

- ME – metabolisable energy
- MJ – megajoules
- RDP – rumen degraded protein
- UDP – undegraded dietary protein (sometimes called 'bypass' protein)
- MCP – microbial crude protein
- MP – metabolisable protein (amino acids)
- VFA – volatile fatty acids

From this digestion, animals absorb:

- volatile fatty acids
- glucose
- long-chain fatty acids
- amino acids
- ammonia.

To be used for:

- maintenance (including activity)
- growth
- lactation
- pregnancy.

Volatile fatty acids

The main volatile fatty acids produced in the rumen are:

1. acetate (acetic acid)
2. propionate (propionic acid)
3. butyrate (butyric acid).

These volatile fatty acids are produced in varying ratios, for example, from 75:15:10 to 40:40:20 (acetate:propionate:butyrate), as diet composition changes.

Acetic acid production is favoured by fibre fermentation (roughage). It is used mostly by the peripheral tissues such as muscle as an energy source and also in the production of fat. Acetic acid is also required to produce milk fat.

Propionic acid production is favoured when there is significant starch and sugar fermentation in the rumen, but even on high-fibre diets, propionic acid is produced in the rumen. It is largely transferred across the rumen wall to the liver where much is converted to glucose. This is a primary energy source for the animal; it provides important components for fat synthesis and is important for liveweight gain and lactose production for milk.

Butyric acid is converted into ketone bodies and carbon dioxide. Ketone bodies are used as a source of energy when there is a diet energy deficiency; for instance, low glucose availability. A rapid build-up of ketone bodies can cause ketosis or milk fever in dairy cattle, usually in early lactation, and it can cause pregnancy toxaemia in goats in late pregnancy. This occurs when there is a sudden rapid increase in demand for energy which the diet cannot supply.

The more rapidly fermentable carbohydrates there are in the diet, the more propionate and butyrate produced. One of the advantages of a high-propionate fermentation is that it is associated with lower methane production than for acetate or butyrate, so there is less loss of energy as methane.

Glucose

Ruminants must make their own glucose because dietary glucose is rapidly fermented by microorganisms in the rumen and is therefore unavailable directly to the animals as an energy source.

Propionic acid and some amino acids are converted to glucose in the liver so it can be used where required. Increasing glucose supply from propionic acid is important because it reduces the need to break down amino acids to produce glucose and it also promotes fat deposition in older animals. Supplements such as maize and sorghum are less readily broken down in the rumen, so some glucose from these feeds, in the form of starch, escapes into the small intestine where it is used directly by the animal rather than by the microorganisms in the rumen.

Diets high in molasses usually favour the production of butyric acid over propionic acid. Ironically, this means that although diets rich in molasses have a high glucose content, the rapid fermentation of that glucose by microorganisms in the rumen and the low production of propionic acid (which is a precursor of glucose), means molasses-based diets are often associated with low glucose supply in the animal. This can lead to reduced fat synthesis in molasses-fed stock.

◆ Dark cutters

The amount of glucose available to the animal post-digestion has significant implications for meat colour. Some glucose is stored in the muscle tissue as glycogen, and it becomes an energy reserve for the muscles.

Depleting muscle glycogen levels before slaughter results in 'dark-cutting' meat. When an animal is slaughtered, glycolysis occurs in the muscle tissue, in which glycogen is converted, in the absence of oxygen, into lactic acid. This normally reduces the pH of the muscle tissue from about 7.2 in a live animal to 5.3–5.7 as it goes into *rigor mortis* (the stage of death whereby the muscles stiffen). When there is less glycogen in the animal's muscles, for instance due to excessive stress and/or nutritional deficiency, then less lactic acid is produced and the carcase goes into *rigor mortis* with a muscle pH greater than 5.7. If glycogen reserves are depleted in the period around slaughter, the pH in the meat remains higher than these levels and dark cutting occurs. Rather than the meat turning a cherry red colour, it becomes dark.

Dark-cutting meat has reduced consumer appeal, it becomes dry when cooked and it has a reduced shelf life.

Muscle glycogen levels are reduced by:

- low-energy diets (dry season, drought), particularly in relation to animal nutrient requirements
- stress on the animals caused by poor temperament or poor handling, such as mixing of non-cohort animals before slaughter
- poor weather conditions when animals are being transported
- animals that are sick, injured, in oestrous, young and unweaned.

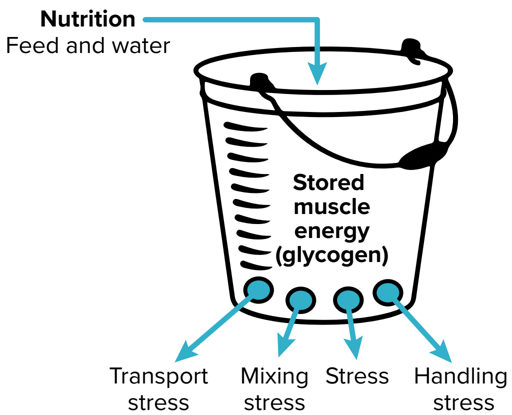


Figure 3: The process of dark cutting (adapted from Beef CRC)

Very small decreases in glycogen levels can significantly impact meat colour and pH.

Fats

Fats are primarily stored in adipose tissue, in the form of triglycerides, as a potential source of energy. Fats are made when there are more carbohydrates in an animal's diet than they need for their immediate metabolic needs. Fat has 2.25 times the potential energy of glycogen on a per unit weight basis. When fats are required as a source of energy, they are mostly broken down in the liver, into ketones and glycerol, and then circulated to where they are needed.

If glucose availability becomes limiting to the animal, for example, during periods of peak lactation, the animal draws on fat reserves to meet this shortfall. This results in production of an excess of ketone bodies, leading to a condition known as ketosis. In cattle, this can occur in peak lactation, most typically in dairy cows. In goats, this occurs in late pregnancy and is known as pregnancy toxaemia and is associated with a large foetus or multiple births. It can lead to abortion or the birth of weak kids.

Amino acids

Proteins, comprised of amino acids, are involved in the production of enzymes, hormones, cells and tissues. They are not directly involved in energy production, except that some are used in the production of glucose.

Water

Water accounts for approximately 70% of an animal's body mass and is used for all essential processes, including:

- nutrient digestion, absorption and metabolite transfer around the body
- waste removal
- thermoregulation
- respiration
- regulating mineral balances
- eyesight
- joint lubrication.

Water requirements of goats vary greatly depending on the moisture content of the feed, the climatic conditions and the physiological state of the animal. For example, a lactating animal requires substantially more water than a non-lactating animal and animals on lush pasture may not require any water at all. Distance between watering points influences frequency of drinking and the amount of water drunk. Water quality can also have a significant impact on water intake.

While the daily intakes of animals in intensive livestock systems (feedlots) can be calculated relatively accurately, very little research has been conducted regarding the water intakes of grazing animals under Australian rangeland conditions. It should be noted that the water consumption of Angora goats grazing dry pastures in summer is greater than similar-sized sheep in the same conditions.

A rough rule of thumb is 10% of liveweight per day on average. This can be used for all classes of grazing animals throughout the year. It is important to remember this is hugely variable depending on season, physiological status, breed, and water content and quality of the feed.

Table 3: Water requirements and salinity tolerances

Class of goat	Water consumption per head per day (assuming dry-feed diet)[1]	Maximum salinity level (total saltsppm) (Scarlett 2002)[2]
Weaners	4–6 litres	7,000ppm
Adult dry goat	5–7 litres	14,000ppm
Doe with kid	5–10 litres	10,000ppm

1 The above requirements for water consumption could double if the temperature exceeds 40°C.
2 When fed diets with salty plant material such as saltbush (*Atriplex spp*), blue bush (*Maireana spp*) or copper burr (*Scerolaena spp*) the maximum salinity tolerances should be reduced by 30%.

The figures in the table above are for goats on a dry-feed diet (dry pasture, grain or hay). The reality of stock water intake is that as the moisture content of the pasture increases, stock get more of their daily water requirement simply from the food they eat and hence require less actual drinking water.

Energy

Energy cannot be created or destroyed; it flows from one form to another. It is not an actual substance like protein or phosphorus. There are several forms of energy, including:

- heat
- light
- chemical (stored)
- kinetic (moving).

Plants can capture the sun's energy and convert it to chemical energy through the process of photosynthesis. The greater a plant's leaf area, the more energy it can capture. Grazing animals harvest the stored energy from plants and rumen microorganisms convert it to a form that can be utilised by the animals.

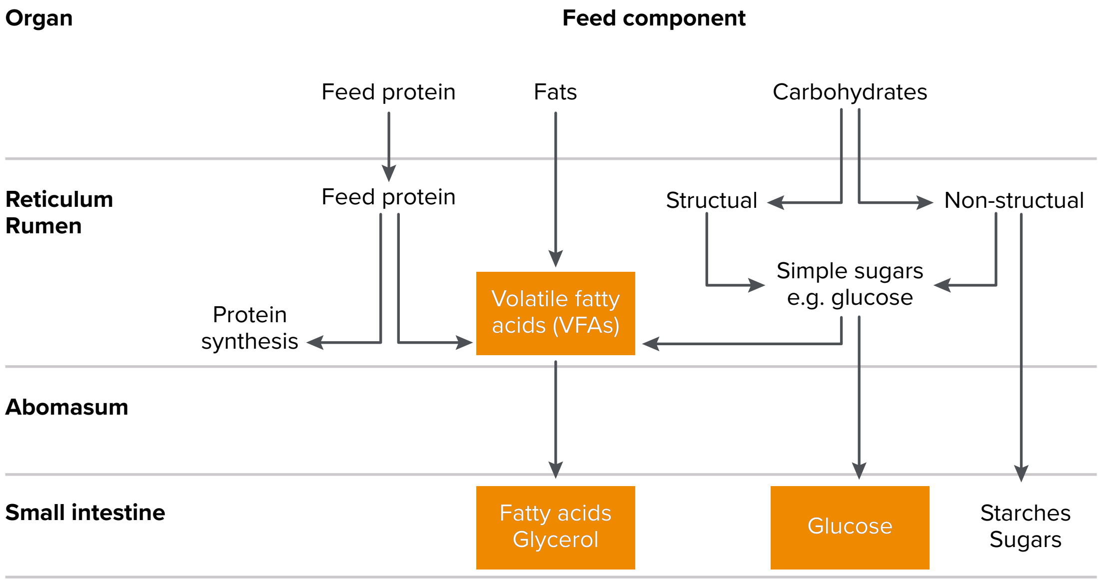
This process of energy capture and transfer is very inefficient. Only a small proportion of the sun's energy is converted into meat; much of the energy is lost as heat and excreted as dung and urine.

The energy content of food for animals is not a tangible substance that can be measured in the laboratory like protein or phosphorus. It represents the capacity of the various components of the food to allow the animal to perform its regular functions, for instance to move muscles, to metabolise nutrients, to digest feed and to produce heat.

The major components of the food that contribute to its energy content are carbohydrates, fat and protein – these components are used in different ways in the animal.

When an animal eats, the chemical energy contained in the food is converted to mechanical energy and heat, similar to the way chemical energy in petrol is converted to work energy and heat in a motor car. The ability of a food to supply energy is therefore of great importance in determining its nutritive value.

◆ Pathways of energy supply



The orange shaded box indicates the site of absorption.

Figure 4: Energy digestion and absorption in ruminants

The energy contained in feed is measured by burning (oxidising) it and determining the amount of heat produced. This represents the gross energy of the food.

However, not all of this energy is available to the animal. Some is unavailable because it is indigestible and some is lost as urine, faeces, methane and heat. The remainder is available to the animal to carry out its regular functions. This component is known as metabolisable energy (ME) and net energy (NE), which represent the useful energy for ruminants and provides the fuel for all the processes an animal performs, including maintenance, growth, pregnancy, milk production and movement.

While energy is not a tangible nutrient, it is common practice to include it under nutrients when discussing the total nutrient requirements of animals.

It is absolutely essential to understand the ME requirements of an animal according to its level of productivity, as this is the basis of ration formulation and pasture budgeting. All ration formulation in Australian livestock systems is based on megajoules.

Digestibility is still a frequently used term, particularly in reference to pastures. Dry matter digestibility (DMD) of grass pastures can be approximately converted to ME using the below calculation.

(MJ ME/kg DM) = 0.172 x DM – 1.707

M/D = energy density of pastures in megajoules (MJ) per kilogram (kg) of dry matter (DM)

- Energy units
  - 1 calorie (cal) = 4.184 joules (j)
  - A calorie is the amount of energy required to warm one gram of air-free water from 3.5 to 4.5°C at standard atmospheric pressure
  - 1 kilojoule (kJ) = 1,000 joules
  - 1 megajoule (MJ) = 1,000,000 joules

- Metabolisable Energy

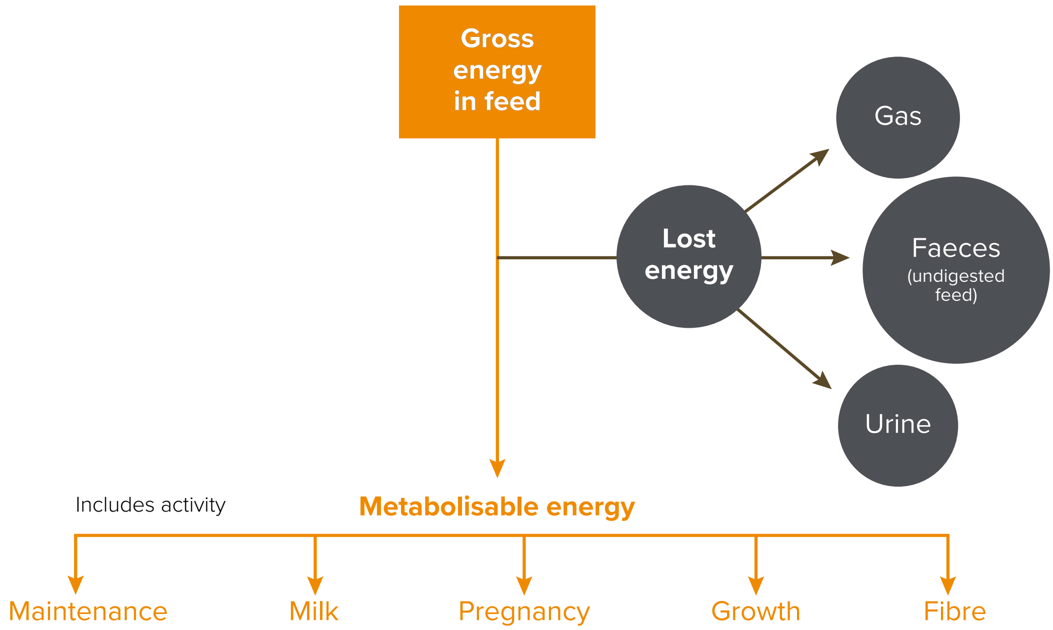


Figure 6: The energy pathway in ruminants

Recommendations for energy requirements for goats are presented in Tool 7.10.

Table 4: Which feed has the most metabolisable energy?

	Type of feed	
	Grain	Straw
Gross energy (MJ/kg DM)	18	18
Digestibility (%)	90	40
Digestible energy (MJ/kg DM)	16.25	7.20
Metabolised (%)	80	80
Metabolisable energy (MJ/kg DM)	13	5.8

Table 5: Typical dry matter, dry matter digestibility and metabolisable energy content of some feeds

Feed	Description	Dry matter (%)	Digestibility (%)	Metabolisable energy (MJ ME/kg DM)
Grain		90	90	13
Molasses		75	90	11
Tropical grasses				
Phase 1	Early, rapid growth	Low (<30)	70	10
Phase 2	Beginning to grow stem, mostly green	Medium (30–50)	60	8.5
Phase 3	Flowering and setting seed, growth slows, 10–30% green	Medium–high (50–70)	55	7.5
Phase 4	Senescence, no growth, no green	High (>80)	50	6.5

Note: Figures for pasture are an estimate of the diet quality selected by grazing animals on pasture at various stages of maturity. The figures for grain and molasses are 'typical' figures but the actual values will vary from those values in the table depending on the quality of the feedstuff.

◆ Temperate pastures

Figures for temperate pastures can be estimated by adding the following to the figures in Table 5.

- Digestibility +10
- Metabolisable energy +1.5

◆ Estimates of the cost of activity as per centage above maintenance

Goats are very active animals and estimates of that energy cost vary widely. Many factors such as feed availability, climatic conditions and water availability will affect the estimates and the tables should be seen at best as a guide to ensure adequate provision is allowed in the calculations. The data provided in the tables below are derived from pen studies but show significant variation.

Table 6: Estimates of the cost of activity as a per centage above maintenance

	NRC (1981)	AFRC (1998)
Pasture	25%	19%
Good range		25%
Poor range	50%	93%
Mountainous	75%	108%

NRC = National Research Council (US) and AFRC = Agriculture and Food Research Council (UK)

Protein

Amino acids are the building blocks of protein. They are relatively small molecules made up of carbon, oxygen, hydrogen and nitrogen, and, in some cases, sulphur and phosphorus. Different amino acids have differing configurations of these elements.

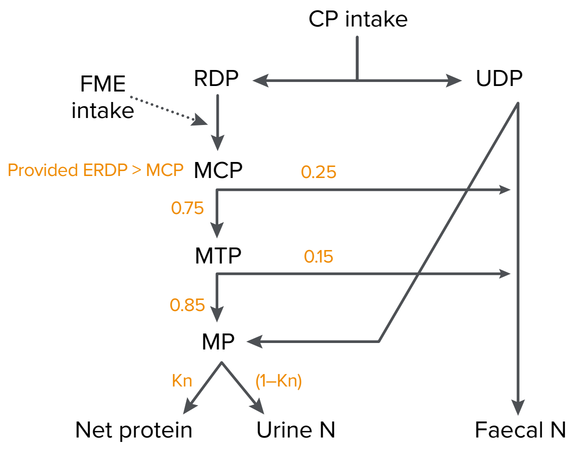
Short chains of amino acids are called ‘peptides’. Chains of peptides form proteins. Amino acids and urea both have an amine group; however, amino acids are distinct from urea (non-protein nitrogen). They have an acid group as part of the molecule, whereas urea does not have the acid group and is therefore not a true protein.

Proteins comprise most of the enzymes that drive metabolism and are incorporated into the hormones that regulate body function. They are a significant component of muscle.

Ruminants eat proteins which are subsequently broken down, either by microbes in the rumen or enzymes and acids in the abomasum, to their basic components; amino acids. The amino acids are absorbed in the small intestine. In the rumen, some amino acids are incorporated by rumen microbes or further broken down to ammonia, which the rumen microbes can use as their major nitrogen source. Ruminants can synthesise protein from non-protein nitrogen sources. Most of the true protein that ruminants eat is broken down by the rumen microorganisms and resynthesised as microbial protein.

There are two important aspects to consider in determining the protein requirements of ruminants. The animal has protein requirements which are intrinsically linked but not directly related to those of the rumen (or the microbes within the rumen) and the rumen has a protein requirement. The challenge is to ensure that both the protein requirements of the rumen and the animal are satisfied. Generally, the protein that is manufactured by microbes in the rumen (microbial protein or MCP) supplies all the metabolisable protein requirements of the animal, except in young growing animals and females in late pregnancy or lactation. These classes of animals usually have a requirement for additional protein called 'bypass' protein.

Protein digestion and absorption



FME = Fermentable metabolisable energy
ERDP = Effective ruminant degradable protein
MCP = Microbial protein
CP = Crude protein
RDP = rumen degradable protein
UDP = rumen undegraded dietary protien
MTP = Microbial tissue protein (proportion of MCP present as Amino Acids)
MP = Metabolisable protein
Kn = Efficiency of utilisation factor for MP
Urine N = Urine Nitrogen,
Faecal N = Faecal Nitrogen

Figure 7: The protein pathway in ruminants

The protein content on most feedstock labels is simply expressed as 'crude protein' (CP); however, this can be broken down further to rumen degradable protein (RDP) and rumen undegraded dietary protein (UDP).

The microbial population in the rumen degrades the RDP to simpler nitrogenous molecules, mostly ammonia, which are used as substrates for the synthesis of microbial cell protein. The UDP passes straight through the rumen where it is either absorbed in the small intestine or is excreted in the faeces, depending on its digestibility. Usually about 80% of dietary protein in roughage feeds and grains is degraded in the rumen. In protein supplements, such as cottonseed meal and copra meal, only 30%–50% is degraded in the rumen.

Non-protein nitrogen (NPN) sources such as urea can be used to supplement ruminants whose diet is deficient in RDP. Urea is 100% rumen degradable and is readily broken down by the microbes into ammonia and contributes to the total supply of effective rumen degradable protein (ERDP). ERDP represents the total nitrogen supply that is actually captured and utilised by the rumen microbes. **Urea must be used cautiously as it is toxic if introduced too quickly to the diet.** The recommended upper limit is 0.5g/kg body weight because animals cannot effectively use more than this amount. The common industry practice is to supplement less than 1% of urea as dry matter (DM) in the diet to prevent ammonia toxicity.

The ruminal microbes require other nutrients as well for their survival, reproduction and growth, particularly sulphur and cobalt (for vitamin B12). Nevertheless, the limitation to microbial protein synthesis is the amount of energy available in the rumen. When nitrogen and other essential nutrients are not limiting, about 8g of microbial protein are synthesised from rumen ammonia for every MJ of dietary ME consumed. It is important therefore to ensure that at least 8g of RDP are available for each MJ of metabolisable energy processed in the rumen.

Urea does not increase the digestibility of the feed, but acts by increasing the rate of digestion and therefore increases dry matter intake.

◆ Metabolic protein requirements

The protein requirements for ruminants are provided in terms of the metabolic protein requirements and not CP contents as listed with feedstuffs, because of the complexities of rumen digestion and the varying degree by which UDP is available to the animal. Tables concerning the metabolisable protein requirements for maintenance and gain of growing goats are presented in Tool 7.11.

◆ Calculating crude protein needed in ration from metabolisable protein requirements

The MP requirements can be reasonably projected to CP needs for most practical purposes, with some assumptions regarding the extent of ruminal degradation of dietary CP.

Values ranging from 0.64–0.80 can be applied to diets with 0 and 100% rumen undegraded protein (UDP), respectively. Diets with 0 or 100% of CP degraded (or undegraded) in the rumen are not typically fed. Thus, CP requirements in the diet have been calculated from the MP requirements of the animal where the level of rumen degradation (DIP; degraded intake protein) extends from 80, 60 and 40%. This equates to concentrations of UIP of 20, 40, and 60%, respectively. A diet with 20% UIP would probably be one of fresh forage where the majority of CP is degraded in the rumen. A diet with 40% UIP might be one with a mixture of concentrate (e.g. high level of corn) and forage. A diet with 60% UIP would contain high levels of protein meals that have considerable protein passing from the rumen intact. Likewise, pelletising usually increases the dietary UIP concentration.

Table 7: Conversion factor from MP to CP

	CP digested in the rumen (%)	Rumen undegraded protein (%)	Factor
Fresh forage	80	20	0.67
Concentrate and forage	60	40	0.70
Meals	40	60	0.74

Using the table above, it can be seen that an animal with a metabolic protein requirement of 48g of MP would have a requirement of 71.6g of CP if it were consuming fresh forage (48 ÷ 0.67), 68.57g of CP if consuming concentrate and forage, and 64.86g of CP if consuming meal. These values demonstrate that as long as available CP is adequate for microbial growth and digestion, the CP requirements decrease as the dietary UDP increases.

◆ Conversion of NPN to crude protein

The concept of microbial growth using non-protein nitrogen (NPN) is one of the most important in ruminant nutrition. The protein per centage can be calculated by multiplying the nitrogen per centage by 6.25. For example:

- urea at 46% nitrogen multiplied by 6.25 = 287% protein (equivalent)
- Gran-am® at 20% nitrogen multiplied by 6.25 = 126% protein (equivalent)
- grass at 1.2% nitrogen multiplied by 6.25 = 7.5% protein.

The basic process of protein digestion and absorption

1. The degradable fraction of the feed protein is broken down in the rumen to peptides, amino acids and ammonia.
2. Urea, ammonium sulphate and other non-protein nitrogen sources can also be used as an ammonia supply for the rumen microbes.
3. The rumen microorganisms then use this ammonia to multiply, i.e. make microbial crude protein. When the microbes are washed from the rumen the microbial crude protein is digested in the abomasum. The resultant amino acids are absorbed in the small intestines.
4. Energy is needed to drive microbial crude protein production in the rumen. Approximately 12 MJ ME is required to grow 100g of microbial crude protein. The optimum concentration of ammonia nitrogen for efficient microbial crude protein production by cattle grazing forages is about 50–80mg/L of rumen fluid – goats and sheep would most likely be similar.
5. The available energy and protein need to be balanced. If energy is deficient, the surplus ammonia is not captured by the rumen microbes but is transferred across the rumen wall, with some lost to the animal by urinary excretion. Similarly, if protein is deficient the surplus energy is used inefficiently in other metabolic processes.
6. The rumen requires approximately 8.25g of rumen degradable protein for every megajoule of energy metabolised in the rumen.
7. There is an upper limit to the rate of microbial protein synthesis. If rumen degradable protein is surplus to this requirement, the excess ammonia can be lost via the urine. This loss of ammonia nitrogen is usually lower under grazing conditions in northern Australia due to recycling of the nitrogen back to the rumen, but is seen on high-protein forages like lucerne or ryegrass. Goats are more efficient at nitrogen recycling than cattle and sheep.
8. This upper limit on microbial crude protein synthesis has implications for high-production ruminants, e.g. high levels of milk production and young growing stock where the requirements are above that provided by the conversion of rumen degraded protein to microbial crude protein. Under these circumstances, the extra protein needs to be provided from protein that is not degraded in the rumen, i.e. undegraded dietary protein which, like the microbial crude protein, flows through to the abomasum and is digested.

Urea

The nitrogen from urea is used by the rumen microbes with about 80% efficiency, provided there is sufficient energy available in the rumen (phosphorus and other minerals are also adequate).

> One of the key roles of urea supplementation is to increase intake of pasture. Most research shows that pasture intake increases by 20–30% in response to urea supplements. Therefore, in order to benefit from urea supplementation, it is essential that there is an adequate supply of roughage in the diet.

◆ Urea poisoning

If the rumen ammonia level rises rapidly, some of the excess ammonia is absorbed through the rumen wall. It is then converted to urea in the liver and either recycled back via the bloodstream to the rumen or excreted.

However, if too much ammonia is produced, it can either cause bloat or be absorbed into the blood stream causing toxicity to the brain and accompanying classical nervous signs. This is the basis of urea poisoning.

◆ Primary limiting nutrient

One of the key principles to understand in animal nutrition is the principle of the primary limiting nutrient. When animals graze, attaining a particular production goal can be restricted by inadequate supply of one or more nutrients, e.g. protein, energy and minerals. Animal performance is primarily limited by the availability of the nutrient most limiting to production, i.e. the primary limiting nutrient.

The supply of nutrients other than the primary limiting nutrient will have no effect on performance until the primary limiting nutrient deficiency is corrected.

As an example of a primary limiting nutrient, animals on low phosphorus soils will respond to phosphorus supplementation in the wet season but not in the dry season. This is because in the dry season protein and energy, not phosphorus, are the primary limiting nutrients and during the wet season, protein and energy are proportionately higher than phosphorus.

Correcting nutrient deficiencies in practice must take place in steps. Correcting one nutrient deficiency will lead to another nutrient becoming the primary limiting nutrient and so on.

It is important to have some knowledge of this hierarchy of nutrient deficiencies. Lack of attention to this simple principle is probably the major cause of economic wastage related to supplementary feeding in practice. Targeting the primary limiting nutrient deficiency is the priority for a cost-effective supplementation program.

In northern Australia's tropical grass pastures, the major nutrients limiting grazing animal growth in the dry season are protein and energy, because of the low protein content and low digestibility of tropical grasses for most of the year.

The exception is where there are specific regional deficiencies, e.g. sodium, sulphur or phosphorus, the latter of which is limiting in a large proportion of northern soils. The main role of phosphorus is to increase intake when energy and protein are adequate.

Inadequate energy and protein intakes are the major obstacles to achieving higher production levels in animals grazing tropical pastures. Supplementation programs should generally be aimed at increasing the supply of these nutrients.

The primary limiting nutrient is protein

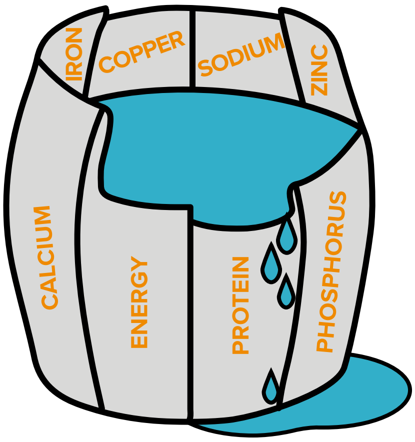


Figure 8: The primary limiting nutrient is protein

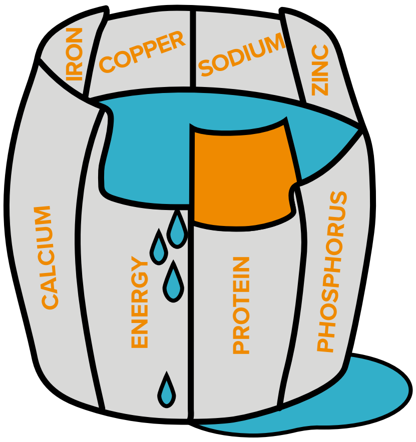


Figure 9: Having fixed the protein deficiency, the primary limiting nutrient is now energy

Fibre

Crude fibre (CF) is a traditional measure of fibre content in feeds. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) are more useful measures of feeding value and should be used to evaluate forages and formulate rations.

Neutral detergent fibre (NDF) is derived by using a neutral detergent agent to remove pectins, proteins, sugars and lipids from a forage sample. The residue then comprises cellulose, lignin and hemicellulose. The level of NDF in the animal ration influences the animal's intake of dry matter and the time of rumination. The concentration of NDF in feeds is negatively correlated with energy concentration. In general, low NDF values are desired because NDF increases as forages mature.

Acid detergent fibre (ADF) is the residual fibrous component of a forage that remains after boiling in an acid detergent solution. It represents the least digestible portion of roughage. It is highly indigestible and includes lignin, cellulose, silica and insoluble forms of nitrogen, but not hemicellulose. Forages with high ADF are lower in digestible energy.

Effective neutral detergent fibre (eNDF) is the per centage of NDF effective in stimulating chewing and salivation, rumination and rumen motility. The basic eNDF is described as the per cent of NDF remaining on a 1.18mm screen after dry sieving.

Example:
The NDF value for barley is 20.11% and the effective fibre component of that barley (as far as chewing and rumination is concerned) is 34%. Therefore, the eNDF value is 6.83% (34/100 x 20.11).

◆ Importance of fibre in goats

Dietary fibre contributes significantly to the balancing of nutrient requirements in goats. Dietary fibre also plays a pivotal role in goat production through its influence on and interaction with the intake and digestion of nutrients. Physiological regulation (feedback from metabolic factors) of intake is dominant in goats fed high-concentrate diets, while physical fill is the predominant factor in the regulation of intake when goats are fed high-forage diets.

Mediated through salivation and buffering capacity, dietary fibre intake influences mastication (chewing) and rumen fermentation. Dietary metabolisable energy densities ≥11.6MJ/kg have been found to depress intake and reduce growth rate in growing goats.

In high production, lactating dairy goats, dietary fibre intake plays a role in the prevention of milk fat depression. The effect is mediated through the maintenance of favourable acetate to propionate ratio in the rumen liquor, as acetate is the major precursor of milk fat.

Research suggests 23% ADF is required for growing goats between four and eight months of age, while 18-20% ADF or 41% NDF is nutritionally adequate for high-producing, lactating dairy goats.

◆ Getting the balance right

Excessive acidity in the rumen can cause problems such as acidosis or ‘grain poisoning’. Chewing fibrous material stimulates the production of saliva which contains natural buffering agents, thus combating rising acidity levels. It is recommended that the ratio of concentrates (grain or pellets) to roughage should not exceed 2:1.

Fibre is slow to break down in the rumen. The breakdown of fibre does supply some energy but too much fibre in the diet can actually restrict intake, which can be undesirable if the animal has high-energy requirements, such as for growth, lactation or gaining condition.

The goal is to achieve maximum production with minimal digestive upsets, as acidosis will decrease intake. The key is to provide a balanced diet.

If using self-feeders, regulate the shutter opening and maintain a good supply of quality roughage hay.

The goal is to achieve maximum production with minimal digestive upsets, as acidosis will decrease intake. The key is to provide a balanced diet.

◆ Using estimated feed value figures

The quality of each ingredient in a ration will vary depending on variety, seasonal conditions, soil fertility, extraneous matter in the sample and spoilage due to wet weather. Understanding and estimating these variables comes with experience. The best place to start is using average figures generated from thousands of samples collated by the US National Research Council (NRC). These are representative only and will seldom accurately predict the ME, CP% or NDF etc, of a particular feed. They do provide very good benchmarks for a range of feedstuffs which can be fed to ruminants. Furthermore, it is generally too expensive to analyse every component of a ration in a small lot feeding situation or for supplementary feeding to fill a feed gap. The easiest approach is to use the NRC tables as a guide and then to simply get the complete ration tested periodically to ensure it is balanced for the main components. It is advisable to seek advice from a professional nutritionist when undertaking long-term ration development or embarking on a large-scale commercial operation.

Below is a sample of feed values as supplied by the US National Research Council.

Table 8: Composition of some common feeds

Ingredient	% DM	ME Mcal/kg	ME MJ/kg	eNDF %	CP %	%UPD (UIP)	CFat %	Crude Fibre	ADF	NDF	% Ash
Barley Grade One	0.90	3.07	12.84	34%	11.66	33.07	3.43	3.37	5.77	14.51	2.40
Barley Grade Two	0.90	3.01	12.59	34%	10.50	33.07	3.30	6.50		20.11	3.35
Corn Grade One	0.85	3.25	13.60	6%	9.00	55.33	4.06	2.29	3.30	10.80	1.46
Cottonseed	0.90	3.36	14.06	100%	21.50	30.44	21.00	25.60	41.80	41.00	4.80
Beans (field)	0.89	3.04	12.72	6%	25.30	50.00	1.50	5.00	3.30	10.80	5.20
Molasses	0.80	2.71	11.34	0%	10.00	15.00	1.30		0.40	–	11.40
Yellow grease (fat)	0.99	6.40	26.78				100.00				
Wheat	0.90	3.18	13.31	30%	14.20	23.00	2.34	3.66	4.17	11.80	2.01
Beet Pulp	0.13	3.04	12.72	33%	10.60	20.00	3.00	20.60		42.00	2.90
Broken Wheat	0.89	2.82	11.80	20%	15.00	0.20	4.00		8.60	20.20	8.43
Alfalfa (Lucerne)	0.90	2.09	8.74	92%	18.70	16.00	1.40	28.00	36.70	47.10	8.50
Apple Waste (fresh)	0.22	2.49	10.42	34%		–	–			41.00	
Brewers Grain	0.25	2.53	10.59	18%	24.00	35.00	1.92	7.80	27.80	42.00	10.00
Corn Silage	0.31	2.39	10.00	81%	8.30	24.00	2.10	20.00	52.50	68.00	8.00
Mill Run	0.86	2.75	11.51	18%	15.00	20.50	5.30	9.50	14.50	36.50	4.50
Wheat Bran	0.87	2.50	10.46	33%	16.00	20.00	4.00	11.00	14.00	42.80	6.60
Wheat Pollard	0.90	2.63	11.00	2%	11.00	21.00	6.00	8.00	15.00	40.00	6.90
Wheat Silage	0.62	2.39	10.00	81%	8.30	24.00	2.10	20.00	52.50	52.00	8.00
Barley Vetch hay	0.90	1.54	6.44	92%	15.90	16.00	1.98	28.00	36.70	55.00	8.50
Canola Meal	0.88	2.49	10.42	23%	40.00	28.00	2.00	13.30	17.00	27.20	7.10
Cottonseed Meal	0.94	2.71	11.34	36%	25.40	43.00	6.00	24.50	17.90	28.90	7.00
Soyabean Meal	0.88	3.15	13.18	23%	51.64	34.00	5.50	5.37	7.00	10.30	6.90
Sunflower Meal LP	0.93	2.35	9.83	23%	38.00	20.00	2.90	23.00	30.00	40.00	8.10
Barley Straw	0.86	1.46	6.11	100%	4.20	70.00	1.40	41.50	48.80	72.50	7.80
Cotton Hulls	0.91	1.52	6.36		8.00		1.70	54.70	65.30	88.30	2.90
Ammonium Sulphate	0.98		–	0%	125.00	–	0.50		2.10	3.00	
Di Calcium Phosphate	0.95		–				0.60		14.60	25.00	

Notes: eNDF% = eNDF as % of NDF
%UDP (UIP) = UIP as % of CP

NB: It is not uncommon to observe minor variations in the values provided. For accurate ration formulation, feed samples need to be analysed by a recognised laboratory.

Mineral nutrition

Grazing animals can generally satisfy their requirements for minerals and vitamins from pasture.

Minerals are important in the nutrition of goats because they are a key component of almost every metabolic process in the body. Macro elements such as calcium, phosphorus and magnesium are key constituents of bone. Deficiencies of minerals can result in ill-thrift, poor growth and fertility, and bone breakages, depending on the specific deficiency.

Goats require 16 different elements in the correct proportions to thrive, the most important being phosphorus and sulphur. Copper, selenium, sodium and cobalt also play important roles.

Both excess and insufficient amounts of minerals can cause problems, either through toxicity or because of secondary effects due to a mineral imbalance. As an example, too much sulphur can cause copper deficiency.

Problems of mineral deficiency or oversupply usually only occur with unusual diets. Most minerals are adequately supplied for grazing animals in the rangelands of Australia. There are some areas of localised mineral deficiencies such as copper, salt, cobalt and selenium. These are, however, more likely to be issues in higher-rainfall regions. This is why it's important to undertake testing before embarking on a supplementation program; there is a significant risk of toxicity in supplementing trace minerals, particularly when a deficiency doesn't exist. There are also situations where minerals are at excessive levels and cause clinical problems, e.g. fluoride in some bores.

Supplementation is the most common means used to correct specific mineral deficiencies, however a balance must be found between delivering optimal amounts of supplements to grazing animals and keeping down the costs of supplementation.

Vitamin deficiencies are not usually a problem for grazing animals except possibly during extended dry periods under certain circumstances, or if a mineral associated with the manufacture of a specific vitamin is deficient in the diet, e.g. cobalt.

Diagnosing mineral deficiencies can be complicated and often requires professional assistance to determine the correct testing procedure and interpret the test results.
The minerals required by animals can be divided into two classes:

1. major minerals (needed in grams per day): also referred to as macro-minerals
2. trace minerals (needed in milligrams per day); also referred to as micro-minerals.

Major minerals

Table 9: Dietary requirements of goats for major minerals (g/kg DM)

Mineral	Dietary requirements (g/kg DM)
Calcium	1.4–7.0
Phosphorus	0.9–3.0
Chlorine	0.3–1.0
Magnesium	0.9–1.2
Potassium	5.0
Sodium	0.7–1.0
Sulphur	2.0

Source: CSIRO 2007

Trace minerals

Table 10: Dietary requirements of goats for trace minerals (mg/kg DM)

Mineral	Dietary requirement (mg/kg DM)
Cobalt	0.08–0.15
Copper	4–14
Iodine	0.5
Iron	40
Manganese	20–25
Selenium	0.05
Zinc	9–20

Source: CSIRO 2007

The dietary mineral concentrations for both major minerals and trace minerals provided in Tables 9 and 10 above should be taken only as a rough guide to those that are desirable. When a range is given, the higher values are for rapidly growing, pregnant or lactating animals, and the lower values are for those at maintenance or with a lower level of production.

NB: Sulphur requirements are better expressed as 0.08g per 6.25g RDP. Concentrations per kilogram of dry matter of sulphur (S) exceeding 3g, molybdenum (Mo) exceeding 2mg, iron (Fe) exceeding 500mg, zinc (Zn) exceeding 100mg, or cadmium (Cd) exceeding 5mg, can have adverse effects on copper nutrition.

◆ Calcium

Calcium is the main mineral found in the body and is mostly stored in the skeleton. Ninety-nine per cent of calcium is found in bone. The amount of calcium absorbed depends on the level of Vitamin D in the diet. It is absorbed largely from the duodenum and jejunum.

Calcium is important for:

- bone and teeth development
- milk production
- heartbeat regulation
- activating enzymes
- blood clotting
- transmitting nerve impulses to muscle.

Calcium deficiencies in grazing goats are highly unlikely, as native pastures usually contain adequate levels of calcium. Nevertheless, deficiencies can arise in very high-milk-producing goats in early lactation as they may develop acute hypocalcaemia/milk tetany. Most cases are seen when pregnant goats have been fed high-calcium diets such as good quality lucerne prior to parturition.

Under such circumstances, the doe's hormone regulatory system has been conditioned to excrete the high intake of calcium, but as soon as lactation starts, the doe needs to draw on her body reserves. The hormonal regulatory pathway cannot switch quickly enough to supply the high levels required for milk production. The doe becomes lethargic and has a poor appetite and decreased milk production. Acute cases of milk fever progress to tetany and coma, requiring calcium borogluconate either intravenously or under the skin; however, these cases are rare in goats.

The condition can be managed by feeding good quality grass/pasture hay prior to parturition. After parturition and when high milk production commences, diets high in calcium can again be fed to supplement the calcium intake and to restore bone reserves so the doe will be ready for her next lactation period.

Tropical pastures high in oxalates (e.g. buffel grass) bind calcium and can induce ‘big head’ in goats. Ground limestone should be provided as a supplement in such situations. Similarly, rations which contain a high proportion of grain need to be supplemented with additional calcium, especially in young, growing goats. These animals may experience enlarged heads as part of a syndrome which is known as osteodystrophia fibrosa which occurs because the high levels of phosphorus which are excreted also drag calcium out of the bones.

» Calcium–phosphorus ratio

A ratio of dietary calcium to phosphorus of 2:1 is assumed to be ideal; however, much wider ranges (possibly up to 7:1) can be tolerated, provided phosphorus is adequate in the diet. The commonly used calcium phosphate supplements contain calcium to phosphorus ratios ranging from 1:1 to 3:1. As such, dry lick or block phosphorus supplements usually contain sufficient calcium to ensure a balanced supplement.

Grains typically have high levels of phosphorus and moderate to low levels of calcium. Weaner rations using cracked grain and cottonseed meal must contain a source of calcium to ensure stock don’t develop soft and fragile bones and rickets. Whole cottonseed and cottonseed meal may contain gossypol, which binds with calcium and further exacerbates calcium deficiencies. In contrast to grain, molasses is low in phosphorus and high in calcium.

The calcium–phosphorus ratio is also important for male goats on feedlot rations as urinary calculi are common. Ensuring adequate calcium and fibre in the diet are important aspects in the management of struvite calculi, as increased chewing ensures phosphorus is excreted via the salivary glands and alimentary canal and not via the urine.

Table 11: Calcium requirements

Goat activity	Calcium requirement in g/day
Maintenance	$\frac{0.623 \times DMI + 0.228}{0.40}$
Liveweight gain	11g/kg liveweight gain
Pregnancy	0.23 g/kg foetus weight in the last 50 days
Lactation	1.4g/litre of milk

Source: NRC of Small Ruminants, 2007

◆ Magnesium

Temperate pastures with a C3 pathway of photosynthesis contain far less magnesium than tropical grasses. Consequently, the condition called hypomagnesaemia or ‘grass tetany’ may occur in southern states, and is rare in the rangelands and northern Australia. The condition is seasonal and is more likely to occur in lush, fertilised, grass-dominant winter pastures. Grass tetany is a complex syndrome which is exacerbated by high levels of potash fertiliser and high levels of protein which decrease magnesium uptake by the rumen.

Magnesium is absorbed in the small and large intestines. Seventy per cent of magnesium is found in bone, 25% in various tissues and organs and 1% in extracellular space.

Magnesium is important for:

- moderating nerve impulses and neuromuscular transmissions
- bone formation
- processing phosphorus-containing substances
- energy reactions
- activating enzymes involved in breaking down proteins
- metabolising carbohydrates, proteins, lipids and nucleic acids.

Table 12: Magnesium requirements

Goat activity	Mg requirement in g/day
Maintenance	(0.0035 x body weight)/0.20
Liveweight gain	(0.40 x average daily gain)/0.20
Pregnancy	(0.006 x kid body weight)/0.20 (last 50 days)
Lactation	(0.14 x milk yield in litres)/0.20

Source: NRC of Small Ruminants, 2007

◆ Phosphorus

Vast areas of grazing lands in Australia are deficient in phosphorus and animals will respond to supplementation in these situations. However, the response can be quite variable depending on the soil types within a paddock. While soil tests will provide a general indication of phosphorus status, they are often not appropriate for implementing a supplementation program, as grazing animals can be achieving adequate phosphorus intake by grazing parts of a property that are adequate in phosphorus.

Phosphorus levels in pasture depend on the stage of growth of the plants in that pasture. In southern grazing systems, superphosphate applications to pastures ensures low phosphorus is not commonly observed. In the rangelands and northern Australia, concentration in the plant is highest when the plant is growing and declines as the plant matures. The concentration in hayed-off pasture may typically be 25% of that in early growing pasture. Nevertheless, it is in the growing season when both protein and energy of the pastures are adequate, that pastures are unable to supply sufficient phosphorus for the animal's requirements in acutely phosphorus-deficient land types. This is when the response to supplement will be seen, as phosphorus is now the limiting nutrient in the diet. Phosphorus deficiency acts mainly by decreasing dry matter intake when both energy and protein are adequate. The main symptoms of decreased intake and poor growth rates therefore occur over the growing season and often go unnoticed because all animals will be gaining some weight; albeit at a lower growth rate.

» Clinical signs

Symptoms of phosphorus deficiency in goats include:

- decreased dry matter intake
- poor growth
- unthrifty appearance
- poor fertility
- osteodystrophy and lameness.

Goats can maintain milk production on phosphorus-deficient diets for several weeks by using phosphorus from body reserves, but during long periods of phosphorus deficiency, milk production was shown to decline by 60%. Phosphorus deficiency is not likely to be seen in intensive production systems but may be seen in the rangelands where soil phosphorus is extremely low. Unlike cattle, goats rarely show clinical signs of lameness, as the duration of lactation in a doe is shorter than a cow.

The calcium–phosphorus ratio should be maintained between 1:1 and 2:1, preferably 1.2–1.5:1 in goats, because of their predisposition for urinary calculi. In cases of struvite calculi, the ratio should be maintained at 2:1.

» Diagnosing phosphorus deficiency

The best diagnostic test is a blood phosphorus analysis. This involves collecting blood samples from young animals during, or just after, the growing season and having the plasma inorganic phosphorus (PiP) levels assessed. Values of 45mg per litre are considered adequate.

» Phosphorus supplementation

Phosphorus supplement must be provided during the wet or growing season to all classes of animals in deficient and marginally deficient areas. P supplement should also be provided to lactating animals in the dry season as milk is high in phosphorus and dry season supplementation helps avoid depleting body reserves.

» Forms of phosphorus available

There are many commercial preparations that can be used as phosphorus supplements. In Australia, all available products registered for livestock feeding must satisfy requirements on minimal levels of cadmium and fluoride. Rock phosphate has relatively low bioavailability for livestock.

- Monocalcium phosphate (MCP) is more available to the animal than dicalcium phosphate (DCP).
- MCP is chemically defined as MCP:DCP ratio ≥ 4:1.
- Chemical mixtures of MCP + DCP = MDCP (mono-dicalcium phosphate (MDCP).
- Higher MCP:DCP ratio = higher bioavailability MDCP.
- MDCP, by chemical definition, has a wide variation MCP:DCP ratio from ≥ 1:1 < 4:1.

» Phosphorus key points

1. Monogastrics (people and pigs) tend to excrete excess phosphorus through urine. The main method of phosphorus excretion in ruminants is via the salivary glands and faeces.
2. Phosphorus absorption occurs predominantly in the small intestine.
3. Most of the signs of chronic phosphorus deficiency, such as ill-thrift, poor growth or weight loss, decreased milk production and low fertility, are primarily due to decreased dry matter intake.
4. The best indicator of phosphorus status is the plasma inorganic phosphorus level of young growing animals just after the growing or wet season.
5. Supplement during the wet season to ensure maximum dry matter intakes in goats.
6. Phosphorus supplementation during the dry season is generally not recommended except for lactating animals.
7. Grain is high in phosphorus and low in calcium.
8. High P levels increase the risk of urinary calculi, especially in wethers. Salt, ammonium chloride (urinary acidifier) and fibre are key elements of calculi management. Fibre in the diet promotes chewing and secretion of saliva (high in phosphates) and this then helps ensure that excess P is excreted via the alimentary canal and not via the urine.

Table 13: Phosphorus requirements

Goat activity	Phosphorus requirement in g/day
Maintenance	0.081 + 0.88 DMI (DMI in kg/day)
Liveweight gain	6.5g/kg of LW gain
Pregnancy	0.132g/kg foetus per day (last 50 days)
Lactation	1g/kg of milk

Source: NRC of Small Ruminants, 2007

◆ Potassium

Potassium is primarily absorbed from the upper small intestine and found in muscle cells where it is readily exchangeable with extracellular fluid. Some potassium is absorbed from the lower small intestine and large intestine.

The functions of potassium include:

- maintaining the acid–base balance in the body
- facilitating glucose and neutral amino acid uptake into cells
- protein synthesis
- maintaining heart and kidney muscle integrity.

There are very few reports of potassium deficiency for ruminants exclusively grazing forages. High-forage diets typically contain several times the amount of potassium present in high-grain diets. Potassium levels decline with increasing forage maturity; however, deficiencies in other elements such as energy, protein and trace elements usually limit production before potassium does.

Table 14: Potassium requirements

Goat activity	Potassium requirement in g/day
Maintenance	(2.6 x DMI + 0.05 X BW)/0.90
Liveweight gain	(2.4 X ADG)/0.90 (ADG in kg)
Pregnancy	(0.042 X kid BW)/0.90 (last 50 days)
Lactation	(2.0 X milk yield in litres)/0.90

Source: NRC of Small Ruminants, 2007

◆ Sodium and chloride

Sodium and chloride are absorbed in the small intestines. They are found in almost all body fluids.

Sodium and chloride are important for:

- acid–base balance
- body fluid balance and osmotic balance
- cellular uptake of glucose
- chlorine required for gastric hydrochloric acid

A deficiency of sodium and chloride results in muscular cramps, cravings, weight loss, reduced milk production and rough coats. An excess of sodium and chloride will result in weight loss.

Some forages, particularly tropical forages, do not normally contain sufficient quantities of sodium to meet the requirements of grazing ruminants throughout the year. This inadequacy is easily overcome by providing common salt *ad libitum*. Craving for salt is the easiest and most obvious criterion for diagnosis of salt deficiency, however urine and saliva are more accurate indicators of salt status. Nevertheless, deficiencies of sodium are not well documented and are not expected to be common. The salt content of many bores is quite high and salt is added to many licks and supplements to regulate intake and as carriers for trace minerals.

Table 15: Chlorine requirements

Goat activity	Sodium	Chlorine requirement in grams/day
Maintenance	(0.015 x BW)/0.80	(0.022 x BW)/0.80
Liveweight gain	(1.6 x LWG)/0.80	(1.0 x LWG)/0.80 (ADG in kg)
Pregnancy	(0.034 x kid BW)/0.80	(0.024 x kid BW)/0.80 (last 50 days)
Lactation	(0.4 x milk yield in L)/0.80	(1.1 x milk yield in L)/0.80

Source: NRC of Small Ruminants, 2007

◆ Sulphur

Sulphur is absorbed as part of amino acids in the small intestine. Sulphur is found in almost all body tissue and in the structure of some proteins, some vitamins and several hormones. It is involved in protein synthesis and metabolism, fat and carbohydrate metabolism, blood clotting and endocrine function.

The responses to feeding urea and sulphur are well documented and a ratio of nitrogen to sulphur of 12 to 1 is generally recommended. Sulphur requirements are better expressed as 0.08g per 6.25g RDP.

» Sulphur deficiency

Signs of sulphur deficiency:

- reduced appetite and weight loss
- reduced microbial protein production.

> Molasses is a good source of sulphur.

Excess sulphur is not common except where significantly high levels are fed in supplements. Restlessness, diarrhoea and muscular twitching are symptoms of sulphur toxicity. The syndrome polioencephalomalacia (PEM) has been associated with high levels of molasses and corn by-products due to inactivation of thiamine by excess sulphur.

Indicative requirements:

- Lactation of dairy goats: >0.16% and <0.36% of DM
- Angora kids: 0.22% of DM for a N:S ratio of 10.4:1
- Mohair production (adults): 3.1 g/day

NB: Seek professional advice if specific issues every arise.

Trace elements

◆ Cobalt

Cobalt is absorbed in the small intestines. It is primarily stored in the liver, but is also found in muscle, bone and kidney. Rumen microorganisms need cobalt to make Vitamin B_{12} which in turn is needed to make propionic acid.

Signs of cobalt deficiency:

- impaired propionate metabolism
- appetite loss
- lethargy
- reduced growth and weight loss
- weepy eyes and anaemia.

Marginal cobalt deficiencies are more likely to occur than severe deficiencies and are generally undetected, although they often result in economic losses. Coastal calcareous sands are usually associated with cobalt deficiencies, however the correlation between soil type and plant levels is poor. Lime and manganese both decrease cobalt availability. Problems usually occur when pastures are lush and very little soil is ingested. Cobalt deficiencies occur when soil levels are less than 0.10mg/kg DM.

Goats with cobalt deficiency have weeping eyes, scaly ears, pale skin and mucous membranes, reduced weight gains and decreased milk production. Angora goats have low fleece weights and poor yields. Perinatal losses can also occur. Wethers are more susceptible than does and young stock are more susceptible than older stock. Codeficiency can predispose goats to yersiniosis bacterial infection.

As B12 levels are low in pre-ruminant animals, the diagnosis of deficiency is based on B12 levels in weaned animals. Treatment consists of administering B12 injections, top-dressing or cobalt bullets which can last up to a year.

Excess cobalt is very rare because the absorption rate of cobalt is low. To be toxic, 300 times the normal requirement must be eaten.

Table 16: Liver B12 as cobalt status indicator

B12 in fresh liver (ppm)	Cobalt status of animal
Less than 0.07	Severe cobalt deficiency
0.07-0.11	Moderate cobalt deficiency
0.11-0.19	Mild cobalt deficiency
0.19 or more	Sufficiency

Source: Larry L. Berger, Ph.D University of Illinois, Salt Institute

Recommended Co levels for goats – 0.11mg/kg of DM *(NRC of Small Ruminants, 2007).*

◆ Copper

Copper deficiency may cause locomotor difficulties in goats in two distinct ways:

- abnormal bone growth with increased bone fragility can lead to fractures of long bones
- a neurologic condition known as enzootic ataxia or 'swayback' develops in kids – permanent myelin degeneration in the spinal cord leads to progressive incoordination and paralysis with failure of mobility.

Copper is important in:

- haemoglobin formation
- iron absorption from small intestine
- iron metabolism from tissue stores
- connective tissue metabolism.

Molybdenum and sulphur decrease copper retention, precipitating a copper deficiency. Lime application to soil increases the availability of molybdenum and can cause copper deficiency. High concentrations of iron in the soil also cause copper deficiency but without the same clinical signs of decreased growth rates and infertility.

» Copper deficiency

Copper deficiency is commonly seen in animals on sandy soils, especially in coastal areas and soils of granite or Pliocene origin. Symptoms of copper deficiency are:

- spontaneous fractures or osteoporosis
- decreased growth rates (especially in young goats)
- infertility
- skeletal defects.

Liver levels (biopsies/abattoir specimens) are the best indicators of copper status, but blood is a more convenient sample to obtain. Plasma copper levels for goats range from 0.9–1.39mg/L.

Copper deficiency can be prevented by inclusion in supplements, drenching and boluses. A correct diagnosis is needed before administering copper as toxicity can be a problem, especially where liver damage has occurred due to pyrriolizidine alkaloid poisoning (e.g. heliotrope toxicity). Copper injections, for instance, have inadvertently killed goats in the past. Animals suffering from excess copper in their diet are generally depressed, lose appetite, pass dark red urine and die. Nervous signs can also be seen in cases of copper toxicity due to liver damage. Only products registered for goats should be used to control copper deficiencies.

Indicative requirements:

- Growing kids 8–10mg/kg DM
- Lactating goats 15mg/kg DM
- Mature goats and bucks 20mg/kg DM
- Growing goats 25mg/kg DM

NB: Adjustments should be made for the levels of molybdenum and sulphur in the diet (NRC 2007).

◆ Iodine

Iodine deficiencies are most commonly seen in high-rainfall regions. The principal site for iodine absorption is the rumen. There is endogenous absorption (i.e. from metabolic processes in the body as opposed to from the diet) of iodine from the abomasum and very little iodine is lost in the faeces.

Iodine is found primarily in the thyroid gland, but it is also found in the abomasum, small intestine, salivary glands, skin, mammary gland, ovaries and placenta.

Iodine is a constituent of thyroxin and other thyroid-active compounds and is in the thyroid hormone that controls the oxidation rate of all cells.

Clinically enlarged thyroid glands (goitre) may be seen in young animals with an iodine deficiency. Levels of <0.2mol/L in milk are a good indicator that a problem exists. A deficiency in iodine causes a decrease in the base metabolic rate and can also lead to infertility, sterility, decreased milk yield, decreased libido and semen quality. Injections and salt licks are usually used in problem areas.

Excess iodine reduces feed intake and daily liveweight gain and gives animals diarrhoea. It can also induce goitre by interacting with the immune system and triggering the development of autoimmune thyroid disease.

Indicative requirements:

- Lactating does   0.8mg/kg DM
- Growing and mature   non-lactating 0.5mg/kg DM

◆ Iron (trace mineral)

Iron deficiency seldom occurs in adult livestock unless there is considerable blood loss from parasites or disease. Iron is absorbed from the small intestine in young ruminants and from the rumen in adults.

More than half the body's supply of iron is found in haemoglobin; the rest is found in the spleen, liver, kidney and heart. A substantial amount of iron is recycled through the body.

Iron is a component of haemoglobin and important enzymes, and is involved in cellular respiration.

Signs of iron deficiency:

- anaemia
- reduced appetite and weight loss
- pale mucus membranes.

Indicative requirements:

- Growing   95mg/kg DM
- Pregnant   35mg/kg DM
- Lactating   35mg/kg DM
- Mohair   Add 5mg/kg DM

◆ Manganese

Manganese is absorbed in the small and large intestines. It is found in all ruminant tissue with concentrations in the liver, kidney, bone, pancreas and pituitary gland.

Manganese is a component of, or activator for, enzymes involved in carbohydrate metabolism. It is also involved in enzyme systems where magnesium is also needed. Higher levels of calcium and phosphorus increase the requirement for manganese.

Signs of manganese deficiency:

- impairs reproductive function
- results in deformed and weak bones with enlarged joints
- severely decreases growth and feed intake
- it takes a while for manganese stores to be depleted from the body.

Ruminants display manganese deficiency only rarely.

Indicative requirements:

Maintenance	0.002mg/kg – body weight/0.0075
Growing	0.7mg/kg – liveweight gain/0.0075
Pregnant	0.025mg/kg – kid body weight/0.0075
Lactating	0.03mg/kg – milk yield/0.0075
Mohair (Angora)	2.5mg/kg – clean fleece weight/(365 x 0.0075)

Selenium

Known selenium-deficient areas include coastal sandy soils, acidic soils, sedimentary and granite soils, usually in high-rainfall regions. Problems are exacerbated in years when rain causes clover dominance due to shallow roots and reduced uptake of selenium from the soil.

Heavy phosphate fertilisation decreases selenium concentrations in pastures, predisposing animals to white muscle disease. Other factors associated with white muscle disease include stress, increased fatty acids in clover and Vitamin E deficiency. Selenium and Vitamin E have similar roles in the prevention of muscle damage by oxidants produced during tissue metabolism, but they have independent sites of action. Selenium treatment therefore reduces the likelihood of muscle damage from combined deficiencies of selenium and Vitamin E.

Green grass is high in Vitamin E and deficiencies are most likely seen in extended dry seasons. Selenium is largely absorbed in the duodenum; however, metabolism in the rumen largely determines the availability of selenium to the animal. It is found in blood plasma and cells.

Selenium is an active component of several microbial enzymes. It is interrelated with Vitamin E and is specifically found in the enzyme glutathione peroxidase which reduces peroxides in the intracellular spaces, that protects cells against oxidative damage. Levels of the selenium-containing enzyme glutathione peroxidase in uncoagulated whole blood of <40 IU are diagnostic for selenium deficiency. Pasture levels of <0.2mg Se/kg DM also indicate a deficiency, but soil levels are usually an insensitive indicator.

Selenium deficiency

Selenium is very toxic and care must be taken to strictly adhere to dose rates when correcting deficiencies. Ensure only products registered for goats are used as deaths due to toxicity from inappropriate administration have been recorded. Injections, drenches and top-dressing with fertiliser have all been used successfully.

Signs of selenium deficiency:

- stiff gait and white muscle disease or muscular dystrophy
- heart failure
- paralysis
- ill-thrift and decreased wool growth.

Loss of appetite and sloughing of hooves are symptoms of chronic excess selenium in the diet.

Indicative requirements:

• Maintenance	0.015mg/kg DMI + 0.083/AC
• Growth	0.5mg/kg – liveweight gain/AC
• Pregnancy (last trimester)	0.0021mg/kg – kid LW/AC
• Lactation	0.10mg/kg – milk yield/AC
• Mohair	0.38mg/kg clean fleece weight/AC

NB: AC = Absorption Co-efficient (forages = 0.31, concentrates = 0.60)

◆ Zinc

Zinc absorption occurs in the small intestine. Zinc is found in many body tissues, but its highest concentration is in the liver, bone, kidneys, muscle, pancreas, eye, prostate, skin, hair and wool. Zinc plasma ranges from 1.12–2.56mg/L.

Zinc is an activator, or constituent, of several enzymes involved in protein synthesis and metabolism. It is also a component of insulin, which is involved in carbohydrate metabolism.

Signs of zinc deficiency:

- dermatitis of neck, head and legs
- excessive salivation
- reduced volatile fatty acid production
- impaired wound healing
- retarded growth and bone formation
- impaired reproductive performance, mainly in males.

High calcium primarily affects zinc absorption, but phosphate also binds zinc. Cadmium, calcium, iron, magnesium, manganese, molybdenum and selenium affect zinc absorption.

Requirements:

• Maintenance	0.045mg/kg – body weight/AC
• Growth	0.025mg/kg – liveweight gain/AC
• Pregnancy (last 1/3)	0.5mg/kg – kid body weight/AC
• Lactation	5.5mg/kg – milk yield/AC
• Mohair	115mg/kg – clean fleece weight/(365 x AC)

NB: AC = Absorption Co-efficient (pre-weaned kid = 0.50, weaned kid = 0.30, adult goat = 0.15)

Mineral interactions

Many interactions occur between minerals, making the diagnosis and management of deficiency (or excess) complex. Higher levels of potassium and nitrogen in the diet will inhibit magnesium absorption. High levels of molybdenum and selenium in the soil reduce copper availability. It is important to be aware of possible interactions.

◆ Cadmium and fluorine

Some phosphorus fertilisers and supplements contain significant levels of cadmium. Although this may not affect animal production, it may result in meat residues exceeding permitted levels for human consumption. Excess fluorine has been observed with drinking artesian water with high fluorine and feeding phosphorus supplements high in fluorine. A safe fluoride limit is <2mg/L, though there are many bores in the Northern Territory and Queensland which are above this level which have not caused issues. Excess fluorine causes teeth problems, lameness and ill-thrift, especially in sheep.

Vitamins

The vitamins include:

- fat soluble (A, D, E, K)
- water soluble (all B vitamins and C).

Rumen microorganisms can synthesise most vitamins. The exceptions are Vitamins A and E which are readily available in high quality forage and Vitamin D which is synthesised by exposure to sunlight.

Vitamins are rarely deficient under grazing conditions. Deficiencies have occurred under extreme drought conditions due to prolonged periods without green feed. Both Vitamin A and Vitamin E deficiencies can occur in drought.

In some cases vitamin deficiencies are induced by deficiencies of specific minerals, e.g. a deficiency of cobalt induces a deficiency of Vitamin B12.

Vitamin requirements for animals are measured in international units (IU). They can be converted to micrograms, however the conversion rate varies depending on the compound making up the vitamin. Examples of differences in conversion are shown below:

- Vitamin A: 1 IU is the biological equivalent of 0.3mcg retinol or 0.6mcg beta-carotene
- Vitamin C: 1 IU is the biological equivalent of 50mcg L-ascorbic acid
- Vitamin D: 1 IU is the biological equivalent of 0.025mcg cholecalciferol or ergocalciferol
- Vitamin E: 1 IU is the biological equivalent of about 0.67mg d-alpha-tocopherol or 0.9mg dl-alpha-tocopherol.

◆ Vitamin A

Vitamin A is found in the liver. It is essential for normal growth, reproduction and maintenance and is a component of visual purple required for dim light vision. Beta carotene is a precursor to Vitamin A and is abundant in green plants and leaves of shrubs. Deficiencies of Vitamin A have been recorded during prolonged droughts.

Signs of Vitamin A deficiency:

- night blindness
- rough coats
- reduced feed intake
- swelling of the joints and brisket
- reduced libido
- abortion, stillbirth and neonatal death
- abnormal semen.

Overzealous use of highly potent forms of Vitamin A can result in toxicity. The upper safe level of Vitamin A is 13,500 retinol equivalents (RE)/kg of diet DM.

◆ Vitamin B complex

A number of compounds make up the Vitamin B complex. The rumen bacteria of goats synthesise the components of Vitamin B complex, therefore it's not necessary to supplement them, nor is a deficiency likely; however, if a cobalt deficiency exists, the production of Vitamin B12 can be inhibited.

Vitamin B12 (Thiamin) is essential for carbohydrate metabolism in the brain. A deficiency in thiamin causes polioencephalomalacia (PEM) or 'goat polio'. Thiaminases produced on high-concentrate feeds or lush pastures deactivate thiamin and induce polio. Increased thiaminase production in the rumen can also occur with prolonged treatment with antiprotozoa substances such as amprolium, the administration of dewormers, ingestion of mulga fern and animals grazing in recently fertilised pasture. High levels of sulphur in the diet are also associated with increased thiaminase activity and PEM. Molasses is high in sulphur. Thiamin up to 1,000 times the requirement is presumed to be safe.

◆ Vitamin C

Goats manufacture their own Vitamin C, hence a deficiency is unlikely to occur.

◆ Vitamin D

Goats exposed to sunlight rarely require Vitamin D supplementation. Vitamin D is important in:

- calcium and phosphorus absorption
- normal mineralisation of bone
- mobilising calcium from bone
- deficiency is unlikely in Australia but has occurred in kids raised in sheds overseas.

◆ Vitamin E

Vitamin E is abundant in green pastures and so deficiencies are usually seen after extended dry seasons or in animals on grain diets. A Vitamin E deficiency usually manifests in young goats as white muscle disease, which is also caused by selenium deficiency.

Vitamin E facilitates the absorption and storage of Vitamin A. Under most conditions, natural feeds supply adequate quantities for adult goats. Vitamin E is also an antioxidant.

◆ Vitamin K

Vitamin K is found in plant leaves and goats also manufacture their own so that a deficiency is unlikely to occur. Care should be taken to prevent goats from accessing rodenticides around sheds as these generally act by blocking the Vitamin K cycle, resulting in inability to produce essential blood-clotting factors.

Purchasing feed

◆ Why use dry matter?

There are several reasons why dry matter is important when considering feed value and purchasing feed:

- water does not add any nutrient value to the ration at all and adds unnecessary transport costs
- similar feedstuffs can be compared more accurately on a cost and nutrient basis
- feed ingredients can be valued accurately only on a dry matter basis, e.g. lucerne hay may have a moisture content of 20% moisture or only 5% depending on its age
- assessing and determining best options for storage – too much moisture causes mould and potential health problems due to aflatoxins.

» Comparison of two feed ingredients with similar feed values on a dry matter basis

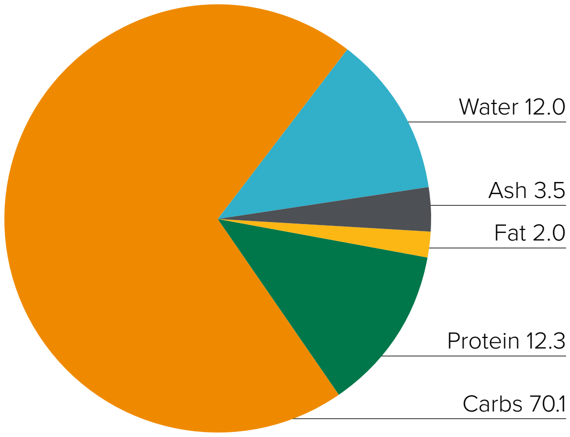


Figure 10: Barley (88% DM)

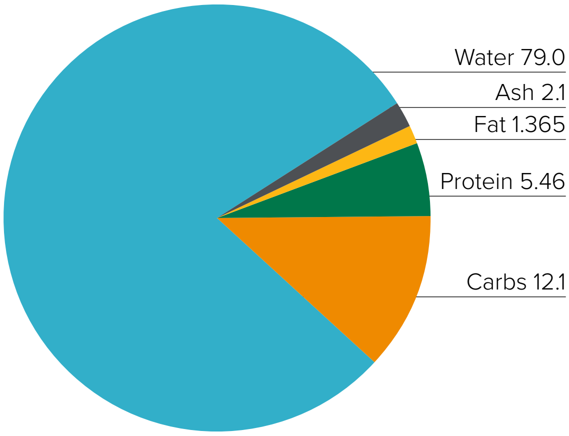


Figure 11: Brewer's grain (21% DM)

On a wet basis, the barley and brewer's grain look altogether different in feed value – but after the water is removed, the two are similar.

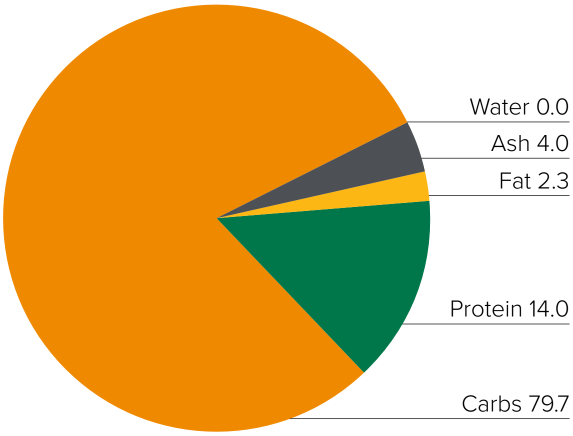


Figure 12: Barley (11.6 MJ)

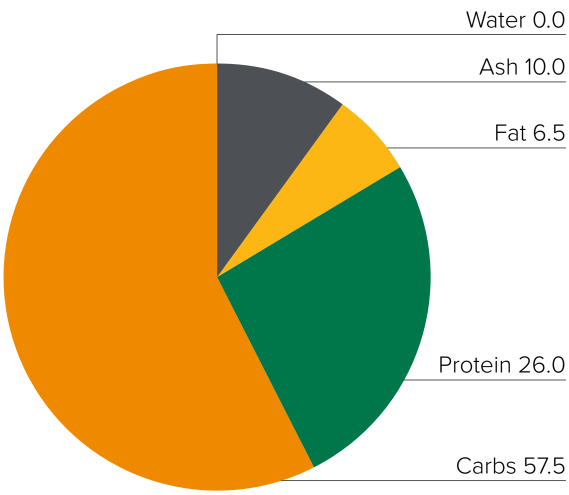


Figure 13: Brewer's grain (10.6 MJ)

QUESTION:
Suppose barley is $200 per tonne, how much should we pay for the brewer's grain?

ANSWER:
Barley is worth $200/0.88 = $227.27/tonne DM

Brewer's grain at the equivalent price/unit MJ = $227.27 x 0.21 = $47.73/tonne WM

Dry matter calculations are also extremely important when freight costs are considered. In the example above, it costs 3.5 times as much to transport a load of brewer's grain than a load of barley on a dry matter basis.

PRINCIPLE: When calculating costs of rations and feed commodities always use the dry matter value of the ingredient.

» Dry matter intake

The general principle is that stock which are being fed a complete and balanced ration should have unrestricted daily access to the ration. The goal is to avoid wastage and to present freshly prepared feed for the animal each day, especially if a high-moisture-content ration is being used. Establishing actual dry matter intakes (DMIs) in these situations is a matter of recording the weight of the daily ration being fed and deriving the dry matter content of that ration. If an accurate feed analysis is available, the liveweight gains or milk production can be predicted from the animals on feed. When the performance is not as expected, issues such as the feeding process, ration formulation and animal health need to be investigated.

DMI is affected by the following:

- digestibility and protein content of ration
- milk yield/lactation status
- moisture content
- palatability
- stress (e.g. worms, heat, cold, disease, weaning)
- age and class of animal.

Milk yield is by far the largest factor that affects DMI and in high-lactating does it can be four times that of a doe at maintenance.

Detailed tables of expected typical dry matter intakes for a large range of breeds, weights and growth rates is provided in Toolkit 7.2.

◆ Feed cost of gain

A key performance indicator (KPI) for animals on feed is feed cost of gain (FCOG). It is the cost of feed/day required to produce the average daily gain.

Suppose a 50kg wether goat on an 11MJ/kg ration DM is eating and gaining 150g/day. Toolkit 7.2 shows he will be consuming 1.18kg/day of a feedlot ration, which costs $450/tonne landed and is 90% DM. If goat wethers dress at 48% and carcase price is $7.00/kg:

- Ration cost = $450/0.90/1,000 = $0.50/kg DM
- Cost of ration/day = $0.50 x 1.18 = $0.59/day
- Value of liveweight gain/day = $7.00 x 0.48 x 0.15 = $0.54/day

In this example, it is costing 59 cents/day to gain 54 cents of liveweight. There are several considerations here:

1. There are other operational costs besides feed in a feedlot operation – labour, vaccination, health costs, running costs and repairs and maintenance.
2. The purchase price ($/kg liveweight) of the goats would have to be less than sale price ($/kg liveweight) to make a profit.
3. The feeding period would need to be as short as possible.
4. The cost of the ration needs to be <$411.86 to have a positive cost of gain.

PLUS:

- **Feed Conversion Efficiency (FCE)** = 1.18/0.150 = **7.87**

◆ Choice of ration

Ration price and quality are the major drivers of the economics of FCOG. The need to source the cheapest ration available is obvious but it must be balanced against quality, which impacts on FCE. The lower the FCE, the better the FCOG.

If animals are taken off pastures and receive all their nutritional needs in a pen, then it is important they received a balanced ration, especially if they are being fed for extended periods of time. Using a commercially prepared and balanced ration or seeking professional advice on ration formulation is recommended in these situations. However, if the duration of feeding is short and if animals have access to good quality hay/roughage, then there are many alternate options that can be considered.

» Cereal grains

Most cereal grains are suitable for use in goats. Grains are generally high in phosphorus, therefore it is recommended to feed ground limestone at about 1% of the ration in an extended feeding regime to ensure the correct calcium–phosphorus ratio is maintained. Minimal processing of grains is required for goats and consequently grain can be fed whole. Furthermore, excessive processing leads to quicker access to the starch and increased risk of acidosis. Grains should always be introduced slowly into the ration. The 'substitution effect' needs to be considered when feeding grain in the paddock. Urinary calculi, especially in wethers, needs to be managed on high-cereal diets.

» Protein meal

Protein meals such as cottonseed meal and copra meal are excellent supplements to feed where there is adequate pasture available. In addition, they provide 'bypass' protein which is often required by lactating animals and young growing animals, as the microbial protein supplied by the rumen is insufficient to meet the protein requirement of the animal. It is often more cost-effective to feed protein supplements than cereal grain in paddock when there is adequate pasture available, as there is no substitution effect with the protein meals.

◆ Changing the ration

Every ration change is accompanied by microbial change in the rumen. Consequently, when goats are removed from their natural pastures into a depot or feedlot, they need to undergo gradual ration change to avoid digestion upsets and need to be vaccinated with a 5-in-1 vaccine to prevent enterotoxaemia (pulpy kidney). Good quality hay or chaff is highly desirable for the first 3–4 days until all animals are eating and settled down. A starter ration should be fed for 1–2 weeks followed by an intermediate ration for two weeks and finally onto the grower ration. Ration change needs to be carefully managed and programmed, especially if they involve major ingredients.

1. Constantly monitor feedstock reserves and anticipate changes well in advance. Even changes from one type of grain to another can cause serious problems, e.g. changing from barley to wheat.
2. If an ingredient comprises more than 10% of the ration, then a changeover period of time is required. If a major ingredient of the ration becomes unavailable and must be replaced with another component – say changing from maize to barley – then there needs to be a transition period between the old and new ration to avoid any digestive upsets. **Do not go directly from the old to new rations without a transition period**. Prepare the new ration at least 10 days in advance of the anticipated change and make gradual increments of change between the old and new ration.

Table 17: Ration change when animals are on high-concentrate rations

DAY	0	2	4	6	8	10
	(100% O)	(80% O)	(60% O)	(40% O)	(20% O)	(0% O)
	(0% N)	(20% N)	(40% N)	(60% N)	(80% N)	(100% N)

1. Ration changes where the per centage of the ingredient is less than 5% can occur over 1–2 days without major adjustment.
2. Where a major change is required unexpectedly, e.g. damage to the feed shed, closure of the supplying factory etc. caution is required, especially if the per centage of grain is increased. In this case, step the ration down by inclusion of good lucerne hay and watch the pH and fibre content of the ration. Keep the pH above 6 and the eNDF above 14.00.
3. Monitor the pens closely during ration changes. If there are any concerns, provide free access to hay (record all hay used) or include it in the ration from the start.
4. Regularly monitor the stock on hand.

A series of instructional videos have been developed to assist producers in forage budgeting and assessing feed nutrition reports. These can be found at mla.com.au/goats.

◆ Winter stasis

The economics of lot feeding goats during the autumn and winter months needs to be carefully monitored. Depending on location and breed, dry matter intake and subsequent average daily gains may be reduced considerably due to the decreasing length of daylight hours. Research in penned goats free of worm burdens and on constant rations, has shown significant decline in performance over the months leading into winter. The full extent of the problem and the exact physiological pathway has not been established, but it is believed to be due to photoperiod effect rather than temperature or feed quality.

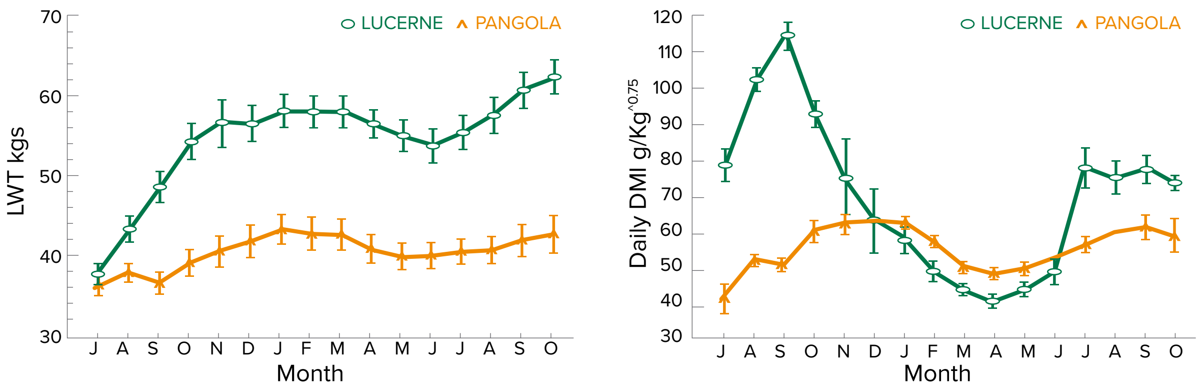


Figure 14: The impact of month of year on liveweight and intake of Angora goats
Source: Walkden Brown et al, 1990

This growth stasis often limits the potential of young goats to reach marketable weights post-weaning and it would appear to affect cross bred and rangeland goats alike at varying degrees.

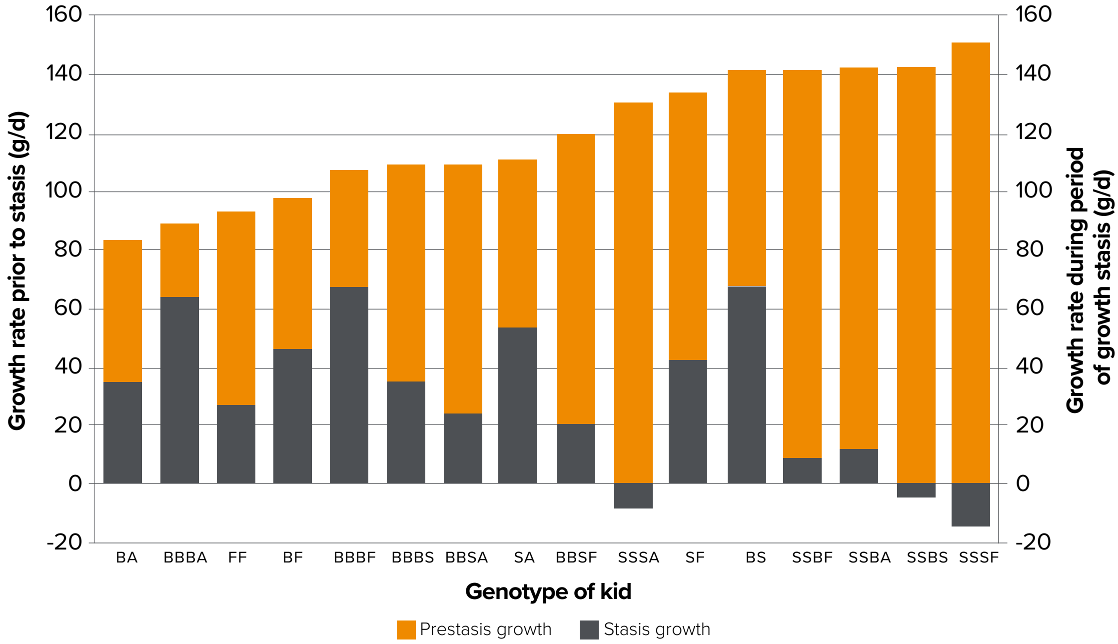


Figure 15: Pre-stasis and stasis growth rates in crossbred Boer (B), Angora (A), Saanen (S) and feral (F) goats
Source: B. Norton (2004)

Feed types

Table 18: Feed types

Feed type	High-energy feeds	Medium-energy feeds	Low-energy-density feeds (sources of fibre and dry matter)	High-protein feed sources
Includes	• Barley • Corn • Wheat • Cottonseed • Molasses • Lupins	• Brewer's grain • Corn silage • Lucerne hay • Mill run	• Barley straw • Cotton hulls • Wheat straw	• Cottenseed meal • Sunflower meal
Further information	Tool 7.13	Tool 7.14	Tool 7.15	Tool 7.16

Purchase of feedstuffs in a feedlot or depot

Sourcing, evaluating and purchasing feed is a continuing and important part of the efficient operation of the feedlot, or goat depot. All feedstuffs (except those that are unpalatable or spoiled) will have some value to a feedlot.

A series of instructional videos have been developed to assist producers in forage budgeting and assessing feed nutrition reports. These can be found on the MLA website: mla.com.au/goats.

The objective is to carefully evaluate the feed, price it and rank it in order of importance. The following steps are a guide to purchase of the feed commodity:

1. **Examine a representative sample** of the feed prior to purchase for contamination, extraneous matter, spoilage, mould, weevils etc.
2. **Establish the category of feed** you are purchasing, e.g. high-energy density, medium-energy density, protein source, roughage or other.
3. **Refer to the library, NRC tables or a reputable reference** for the **feed values** of the feed in question – dry matter, energy density, protein level, fat content, fibre content.
4. **Examine the cost on a dry matter basis** for the actual content in which you are interested, e.g. energy.

$$\frac{\text{Cost of feed (cents per kilogram) x 100}}{\text{DM per centage x ME MJ/kg}}$$

Example:
Barley @ $280/tonne with DM = 90%

$$\frac{280 \times 100}{1000 \text{ X } 0.90 \times 12.5} = 2.49 \text{ cents/MJ DM}$$

This can be ranked against the value of barley from previous purchases or, alternatively, it can be ranked against other sources of energy that may be available at the time.

The most important ingredients to consider in a feedlot operation are energy and then protein. A spreadsheet calculator can be easily constructed in Excel and will provide a useful tool when preparing rations and ordering feed. In the example listed below, barley happens to be the cheapest source of energy.

Table 19: Energy and protein calculator example

	Energy and protein calculator					
Ingredient	Price/ tonne	% DM	ME in MJ	Protein %	Unit cost ME Cents/MJ	Unit cost protein $/kg
Wheat	$310	90%	13	12.0%	2.65	$2.87
Barley	$280	90%	12.5	14.0%	2.49	$2.22
Whole cottonseed	$450	90%	13.5	23.0%	3.70	$2.17
Cottonseed Meal	$500	89%	10.5	45.0%	5.35	$1.25
Lucerne Hay	$450	85%	10	25.0%	5.29	$2.12

Performance of goats on pastures

The main nutritional challenges to consider when grazing goats on native pastures include:

- the inability to accurately determine the intake and quality of the diet being consumed on a daily basis
- the seasonal nature of the feed on offer with regard to both quantity and quality
- the skill to match available pastures with the animals' nutritional requirements
- quantifying the cost of the feed being provided.

Measures of pasture quantity and quality

Pasture quantity is measured in kilograms of dry matter per hectare (kg DM/ha). The dry matter of a pasture varies with the stage of growth and the species. Young green pasture can be about 20% dry matter (80% moisture) while mature frosted pasture can be 80–85% dry matter (15–20% moisture); hay is generally about 20% moisture or less.

Pasture quality is a measure of the concentration of nutrients in a pasture. By far the most important nutrients are energy and protein. The three important measures of pasture quality are:

1. digestibility (%)
2. metabolisable energy, measured as megajoules (MJ)
3. protein content (%).

The energy content of pastures is usually expressed in terms of the digestibility of the pasture or digestible organic matter in dry matter (DOMD%). There are various formulas for the different types of pasture, but the one most frequently used that provides an indication of the megajoules of energy in a pasture sample is as follows:

- M/D (MJ/kg) = 0.172 x DOMD% – 1.707 (M/D = energy density of pastures in MJ/kg of DM)
- If a pasture sample has a DMD of 60%, this equates to 8.6 MJ/kg DM.

Principles of pasture growth and quality

Pasture growth (quantity) is seasonal and pasture quality closely follows this seasonal pattern. The growth pattern of pasture plants is controlled by seasonal fluctuations in:

- water availability
- temperature
- day length.

The important feature is that the seasonal pattern of growth, and hence quality, results in large variations in plant quantity and quality. For many native pastures, quality declines rapidly after flowering starts. Frosts reduce plant quality even further.

Water is the most limiting environmental constraint to pasture growth. Temperature, both high and low, also limits growth. In the tropics and subtropics, animal growth rates closely follow changes in pasture growth associated with rainfall.

Water availability is affected by:

- rainfall (varies according to intensity and seasonality)
- infiltration (regulated by soil type and structure, slope and ground cover)
- water holding capacity (determined by soil type and clay content).

Rainfall use efficiency, which is a measure of kilograms of dry matter grown per hectare per millimetre of rain, is a useful measure of how rainfall is converted into pasture growth. It can be used to compare land types and their condition.

Other factors that have a major influence on pasture growth and quality are:

- land type (including soil type)
- pasture age
- pasture type or species.

◆ Pasture quality

Pasture quality is most directly affected by soil fertility and in particular the availability of macronutrients (i.e. nitrogen, phosphorus, potassium and sulphur). The availability of micronutrients (e.g. magnesium, calcium, copper, zinc and cobalt) can also directly affect pasture quality and animal performance.

Different soils have different levels of inherent fertility. Each has a natural limit to the amounts of various nutrients made available to plants. The availability of nutrients to plants can be maximised through management. Ensuring high levels of soil organic matter enhances soil structure, water holding capacity and nutrient cycling.

The key to maintaining high levels of soil organic matter is to only graze a small proportion of pasture (20–40%) leaving plenty to protect the soil and remain as organic matter.

◆ Pasture age

Plant cells contain the following nutrients:

- carbohydrates
  - structural (cellulose)
  - non-structural (starch, sugars)
- proteins
- minerals
- lipids.

Plant cells have a cell wall made of structural carbohydrates that are digested by microbial fermentation in the rumen. The nutrients found in cell walls include:

- cellulose
- hemicellulose
- lignin
- bound proteins
- bound minerals.

Non-structural or soluble carbohydrates (simple sugars and starches) are the plant cell contents and are more easily digested by goats. Generally, as pasture plants mature:

- structural carbohydrates increases
- soluble carbohydrates decrease
- lignification increases
- the leaf to stem ratio decreases
- protein (nitrogen) concentration decreases.

These changes in the relative proportions of nutrients associated with plant maturity have a marked effect on quality. As pastures age:

- digestibility decreases
- metabolisable energy decreases
- protein decreases.

The rate of decline in digestibility varies between species and between plant parts:

- grass digestibility declines more rapidly than herbage and legume digestibility
- stem digestibility declines more rapidly than leaf digestibility.

Changes in the chemical composition of grasses as they age (per centage composition of cells)

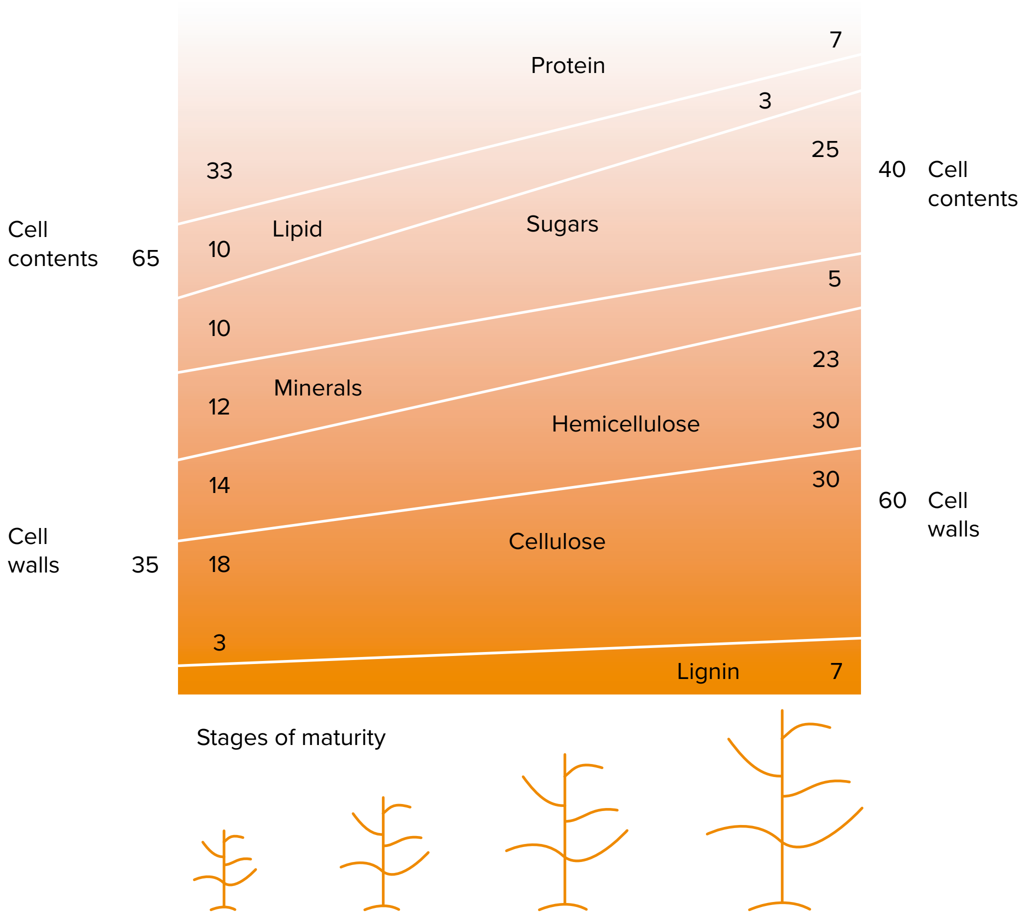


Figure 16: Changes in the chemical composition of grasses as they age (per centage composition of cells)

Figure 16 shows the decline in quality of pastures as they age. The values in Table 20 are general and will differ with changes in plant and soil type. The values are indicative of the quality of some feeds and the diet quality of animals grazing these pastures.

While higher pastures tend to have lower nutritional value, they may also have fewer worm larvae, especially as goats tend to graze from the top down.

Table 20. Examples of dry matter, dry matter digestibility, metabolisable energy and crude protein content of some feeds

Feed	Description	Dry matter (%)	Digestibility (%)	Metabolisable energy (MJ ME/kg DM)	Crude protein (%)
Grain		90	90	11–13	8–12
Molasses		75	90	11	4.3
Tropical grasses					
Phase one	Early, rapid growth	Low (<30)	70	10	10–16 (12–16*)
Phase two	Beginning to grow stem, mostly green	Medium (30–40)	60	8.5	8–10 (10–12*)
Phase three	Flowering and setting seed, growth slows, 10–30% green	Medium-high (50–70)	55	7.5	6–8 (7–10*)
Phase four	Senescence, no growth, no green	High (>80)	50	6.5	3–6 (7*)

*The crude protein (%) for tropical grasses plus legume pasture.

Note: Figures for pasture are an estimate of the diet quality selected by grazing animals on pasture of various stages of maturity. The figures for grain and molasses are 'typical' figures but the actual values will vary from those provided in the table.

Temperate and tropical pastures

The most important difference between tropical and temperate pastures is how they use sunlight. All legumes and the temperate grasses have a C3 pathway of photosynthesis, while tropical grasses have a C4 pathway of photosynthesis. Tropically-adapted pastures grow in warm climates, use water and nitrogen more efficiently and are higher yielding. The down side is that tropical pastures have a shorter growing period, are more fibrous and are less digestible than temperate pastures at the same growth phases. They generally contain lower protein and lower calcium and phosphorus, but have higher magnesium levels. Temperate grasses, such as rye grass, are more easily digested than any of the tropically-adapted pastures, such as Rhodes grass or black speargrass.

Pasture management is the key component of a sustainable and productive pastoral grazing enterprise. It has often been stated "get the pasture management right and the animal management will follow". While the basic principles and science of pasture growth are the same in the north and south, the actual management strategies are quite different and will be discussed separately in this module. The major difference relates to rainfall variability and distribution which has a significant impact on pasture productivity, utilisation rates, stocking rates, feed availability and even fodder conservation. The higher stocking rates found in southern Australia ensure that pasture renovation, fertiliser application and other inputs are economically sustainable whereas the much lower stocking rates usually found in northern regions dictate a completely different approach to pasture management.

Because much lower stocking rates impact the returns per hectare from animal production, the main emphasis in northern pastures systems is to ensure they are managed with minimal input and are sustained in optimum condition and with minimal rundown. Furthermore, the pasture growth patterns of a very active but relatively short growing season followed by a regular extended dry season underpins the subsequent animal productivity originating from such regions.

- Tropical pastures

Pasture growth and development can be divided into four phases.

Phase one
Plants are growing rapidly and producing high quality green leaf. Pastures are most nutritious in phase one but are susceptible to overgrazing which can lead to deterioration of the root mass. Pasture quantity may restrict intakes of grazing animals. Feed is most nutritious at this stage.

Phase two
Plants begin to grow stem that is lower quality. They are less susceptible to grazing and quantity is higher. This is the most favourable stage for grazing pastures. Feed is very nutritious at this phase but lower than at phase one.

Phase three
Plants set seed and quality declines rapidly. Pasture bulk is usually not limiting in this phase. Little growth will occur from now on. This is often the stage at which hay is made.

Phase four
Plants become dormant. Quality is low and declines further with frosts and small falls of rain. Figure 17 illustrates the different phases of pasture growth.

Pasture growth phases

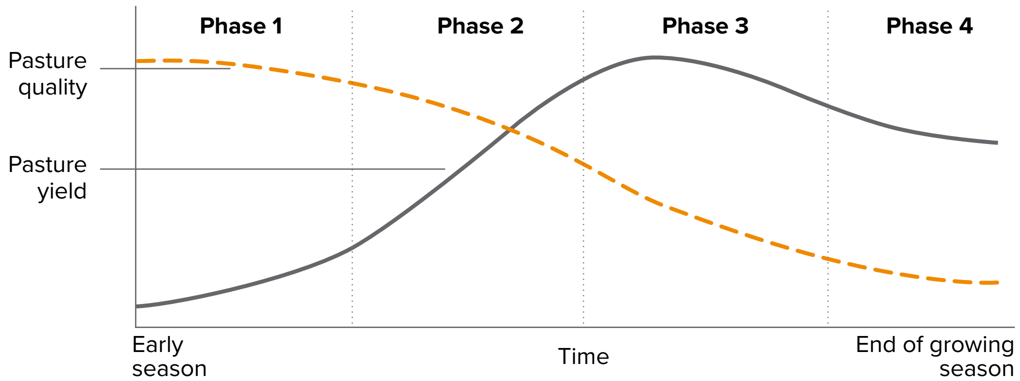


Figure 17: Phases of pasture growth of tropical pastures

The decrease in pasture quality as pastures age has a marked effect on livestock productivity.

- low digestibility depresses intake and increases rumen retention time
- low metabolisable energy content reduces animal performance
- low protein content reduces the efficiency of microbial fermentation.

The proportion of green leaf in the pasture is a good indicator of feed quality. Ruminants select leaf in preference to stem, and green leaf in preference to dead leaf. The critical lower limit of green leaf is about 10%; stock have trouble selecting green leaf when there is less than 10% available. Once the proportion of green leaf reaches 30%, nearly all the diet selected is green leaf.

Pasture composition

Factors affecting palatability include:

1. **Chemical composition of the plant.** The more protein, sugar, acetic and butyric acid, and linolenic acid a plant contains, the more palatable it is.
2. **Growth phase of the plant.** Younger plants are generally selected preferentially to plants in latter growth phases.
3. **Environmental conditions, including climate, topography and soil moisture.** These factors affect both the chemical composition and harshness of the plant parts (e.g. leaves).
4. **Physical attributes of the plant** – thorns, stickiness, hairy leaves, accessibility to leaves on the plant and texture all can reduce an animal's ability to select those plants.
5. **What else is on offer?** Some plants can be very palatable; however, if there are other more palatable plants, these may be selected preferentially. This will vary on soil type and land type.
6. **Temperature, grazing area, water availability.** These all affect grazing behaviour and the animal's ability to be selective.
7. **Rainfall and rainfall pattern.** This will affect the palatability of plants.
8. **Species of animals.** Cattle, sheep and goats all have different grazing behaviour. For example, goats browse more readily than cattle and sheep do.

The types of plants in a pasture influences the pasture's growth and quality and its ability to supply nutrients to grazing animals. The main groups and differences between plants are:

- legumes and grasses
- temperate and tropical pastures
- 3P grasses
- annuals
- unpalatable grasses.

Legumes and grasses

Unlike grasses, legumes can fix atmospheric nitrogen and are generally of much higher quality; quality which is retained longer into the season than is the case with grasses. Young green shoots of black speargrass can have a level of protein of 15–18%, whereas the young growing tips of the shrub legume leucaena can have a protein level up to 28%.

Generally, animals grazing pastures with high legume content have much better diet quality than those on unfertilised grass only pastures. Unfortunately, goats tend to prefer grasses over medics in mixed pastures (especially when the medic is young and green). Legumes tend to have a requirement for higher levels of soil phosphorus than do grasses and are more susceptible to overgrazing. Good pasture spelling systems need to be implemented to ensure introduced legumes persist.

3P grasses

In arid and semi-arid production systems the 3P grasses become the prime focus for grazing management. The 3P grasses are perennial, productive and palatable. A pasture with a high proportion of these grasses (for example, more than 70% by weight) is in better condition, is more productive and allows grazing animals better selection.

Indicators of pasture quality

The amount of 3P grasses provides some indication of pasture quality for livestock production although they are a better indicator of pasture condition. Leafiness is another indicator of plant quality (recall that leaf is more digestible than stem and is selected by animals). A good comparison would be between a leafy grass (e.g. Queensland bluegrass or black speargrass) with a stemmy grass (e.g. wiregrass).

The amount of legume in a pasture and the amount of green are also good indicators of pasture quality for grazing animals.

Summary of pasture quantity and quality

In our environment, water availability limits pasture growth (quantity) most significantly. It is largely determined by rainfall, its seasonal distribution and soil type (land type). Land condition (pasture species composition, soil condition and tree density) also affects pasture growth.

The things that have the greatest influence on pasture quality are:

- land type
- pasture age (growth phase)
- pasture type (species).

The more fertile the land type, the higher the pasture quality. As pasture plants age (mature):

- digestibility declines
- nitrogen content declines
- the leaf to stem ratio declines
- animal performance declines.

The differences between plant species are:

- legumes are higher in digestibility and protein than grasses
- temperate pastures are more digestible than tropical pastures
- 3P grasses are perennial and have a well-developed root system which stabilises the soil
- while annual grasses can be high in digestibility and protein, they signal pasture decline.

◆ How do you assess pasture quality?

Pasture quality can be visually assessed to a large degree by observing:

1. Plant species, including plant types such as grass, herbage and legumes
2. Growth phase
3. Availability of green leaf
4. Leaf to stem ratio
5. Proportion of green leaf – once green leaf drops to a threshold of 10%, very little green leaf can be accessed by goats.

Production is a function of the quality of the diet and the level of intake of pasture. Pasture can be very high quality but limiting in availability, such as in the early stages of growth of pasture following rain and coming out of a dry spell. At this time, the dry matter content of the pasture is very low which means that animals have to consume a large quantity of pasture to achieve their potential dry matter intake level.

Although pasture assessment is very good for making an initial assessment of pasture quality, animal grazing behaviour and diet selection dictate the quality of the diet they consume, which can only be assessed through a diet quality analysis, which will be explained further.

Temperate pastures

◆ Grazing temperate pastures

Southern Australia pasture systems are under the influence of a Mediterannean type climate – hot dry summers, cold wet winters and relatively reliable rainfall which translate as an autumn break and a seasonal flush of feed in spring that carries over into the summer when there is traditionally a high bush fire risk. Effective pasture utilisation is the key indicator for successful pastoral enterprises.

In temperate grass-based pastures, it is common to think about pasture growth in terms of the number of green leaves. Grass tillers are only able to maintain a certain number of green leaves before the oldest leaf starts to decay. Decaying leaves are of low feed quality and lower palatability, and thus represent wasted production. The aim is to graze as many green leaves as possible and minimise decay. For example, perennial ryegrass has, at most, three active green leaves per tiller; the fourth leaf onward will be decaying. The aim is to commence grazing when there is an average of three green leaves per tiller.

Other common temperate grass species function similarly and hence a similar grazing strategy is appropriate. Phalaris has a maximum of four active green leaves. Cocksfoot and fescue have at most five active green leaves. Having determined when to commence grazing, the next questions are when to take stock out and how long to spell the paddock before the next grazing. This is governed by the rate of plant recovery and growth. The recovery of temperate pasture grasses after heavy grazing is initially quite slow. The rate of growth rapidly increasing as more leaves appear, reaching a plateau, and then declining as decay begins to surpass new growth.

Because of much higher stocking rates, slower growth rates and a lack of a prolonged dry season every year, temperate pastures are managed in three phases of growth not four phases as discussed earlier under tropical pastures.

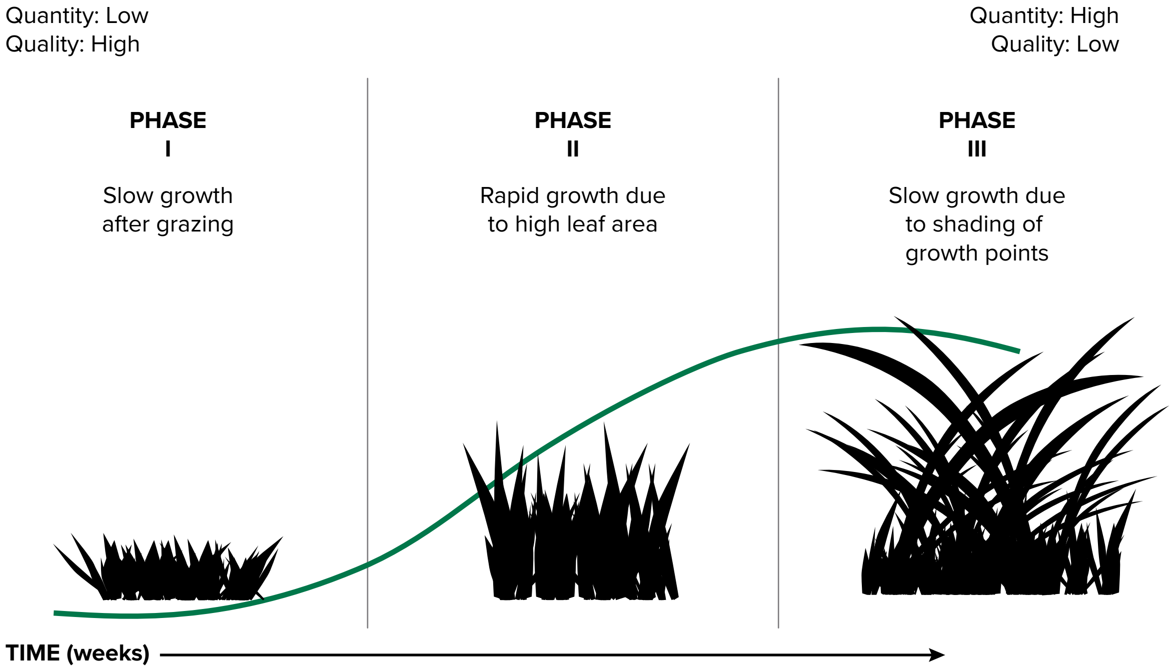


Figure 18: Phases of pasture growth of temperate pastures
Source: PROGRAZE®, DPI Victoria, MLA 2005

Phase one

- very short pasture
- low leaf area, very little interception of sunlight
- initial regrowth is often driven from plant energy reserves
- slow pasture growth
- high quality feed, low quantity.

Phase two

- phase of greatest pasture growth
- increasing leaf area allows increased photosynthesis and thus increased biomass production and replenishment of plant energy reserves
- good quality and quantity.

Phase three

- high leaf area, but shading of lower leaves and decay, reduces the growth rate
- high quantity, low quality.

The aim of grazing management is to spend as much time in phase two as possible. This is where you get the greatest pasture growth, striking a good balance been feed quality and quantity. As displayed in the previous diagram, the lower the level of leaf area remaining at the end of grazing, the slower the rate of plant recovery. It is advisable to retain some leaf area at the end of the grazing period.

If pastures are subject to frequent heavy grazing and are continuously kept in phase one, individual plants will begin to suffer and some will be killed. Loss of desirable plant species opens up the pasture to weed invasion. Also with reduced plant cover, the soil surface is exposed, increasing the risk of erosion.

At the other end of the scale (phase three), prolonged periods of infrequent or lax grazing lead to large quantities of very low quality feed. In tall pastures very little light gets down to the growing points at the base of the plants, and lower growing species may be completely shaded. As a consequence, low growing plants often do not survive and the formation of new grass tillers is suppressed. Thus the pasture starts to thin out.

The rate at which each new leaf appears is governed by moisture and soil temperature. If one or both of these is limiting, the rate of appearance of new leaves will be slow. For example, in summer, soil temperature is not a limiting factor, but there is often a deficit of moisture, hence summer growth rates are often slow. In spring, when soil temperature and moisture conditions are optimum, pasture growth is very rapid. The frequency of grazing needs to be adjusted accordingly, with long rest periods between grazings when growth rates are slow and more frequent grazing when growth rates are high.

Anti-nutritional factors

Tannins are polyphenolic substances which can bind to proteins and inhibit digestive enzymes from breaking down the proteins. The level of tannins in plants is inversely proportional to soil fertility. Tannins bind up sulfur and when diets are high in tannins, e.g. mulga-based diets, additional sulfur may be required in the diet. Goats can cope better with high tannin levels than either sheep or cattle. On a positive note, high tannin levels offer some protection from worms.

Volatile or essential oils found in some browse shrubs inhibit rumen microbial function, depressing cellulose digestion and volatile fatty acid levels in the rumen. However, not all volatile or essential oils inhibit digestion.

- Measures of nutrient status of the pastures

1. **Blood**
   Blood analysis is generally not used to establish the nutritional status of animals for energy and protein. However, blood samples are useful for establishing deficiencies of phosphorus, copper, selenium and cobalt.
2. **Dietary crude protein**
   The dietary crude protein level indicates the level of protein in the diet. The total intake of protein depends on how much pasture the animals eat, which is affected by digestibility. This means that it is not necessarily the per centage of protein in the diet that gives the best indication of the protein status, but the total intake of protein which is a function of the protein per centage and digestibility.

   Protein is usually the first nutrient to decline in the diet once pasture begins to mature and dry; however, this is not always the case.

   Dietary crude protein can be high when there is a significant amount of native browse in the diet. As much of this protein can be bound up in tannins, the amount of protein available for digestion is often much lower than what the result indicates.
3. **Dietary digestibility**
   The dietary digestibility or dry matter digestibility level indicates the animals' potential dry matter intake of pasture and the energy level in the pasture. This does not take into account factors such as the yield of pasture available for grazing, the leaf to stem ratio and the species composition. This means that even though the digestibility can be high in some instances, for example, when there is a break in the growing season, you must consider whether there is enough pasture available to meet the intake requirements of the stock.
4. **Faecal nitrogen**
   Faecal nitrogen is positively correlated with dietary crude protein. If dietary crude protein is low then the faecal nitrogen level is also low and vice versa.

5. **Non-grass proportion of the diet**

The dietary non-grass component refers to all herbage, legumes, browse and bushes that are grazed. If the non-grass component is primarily comprised of herbage and legumes, it will be contributing valuable nutrients to the diet provided it makes up a significant proportion of the diet. It is the presence of herbage and legumes in the diet which really drives production.

If the non-grass is primarily comprised of browse, then the diet quality will likely be low.

6. **Ash**

The ash content is the inorganic fraction in the diet. The normal ash range is from 18–22%. When the ash exceeds this level, it is usually due to soil contamination. A high ash level causes an over prediction of dietary crude protein, digestibility and non-grass.

» Dry matter digestibility to crude protein ratio

The dry matter digestibility to crude protein ratio indicates the balance between energy and protein. The higher the ratio, the closer to the dietary threshold at which animals will respond to a nitrogen supplement.

Grazing behaviour

In the past, pasture assessments in the arid and semi-arid regions were based on the grazing behaviour of sheep; however, the grazing habits and dietary preferences of goats differ from sheep. These differences need to be understood when developing long-term carrying capacities and performing annual forage budgets and pasture assessments. The techniques for pasture assessment in the rangelands therefore must accommodate an assessment of the edible top feed or browse as well as the grass component of the diet.

In a major study of the poplar box woodland communities of western NSW and south-west Queensland, where diet quality varied throughout the year with the per cent of nitrogen in the range of 0.98–2.10% and in vitro digestibility values ranging from 42–61%, it was found that goats ate more shrubs than either cattle or sheep and that they were able to graze in inaccessible places, for example dense thickets and up trees.

A later study found unmanaged rangeland goats differed to all other herbivores in that their diet was dominated by browse. Sheep and cattle exhibited a broader diet, containing relatively large amounts of grass and browse. There was a large dietary overlap between grey kangaroos and wallaroos, and sheep and cattle. The macropods were found to be dominantly grass consumers, with grass comprising approximately 90% of their diets. The red kangaroo differed to the other macropods in that they consumed a greater amount of forbs and browse. See Figure 19.

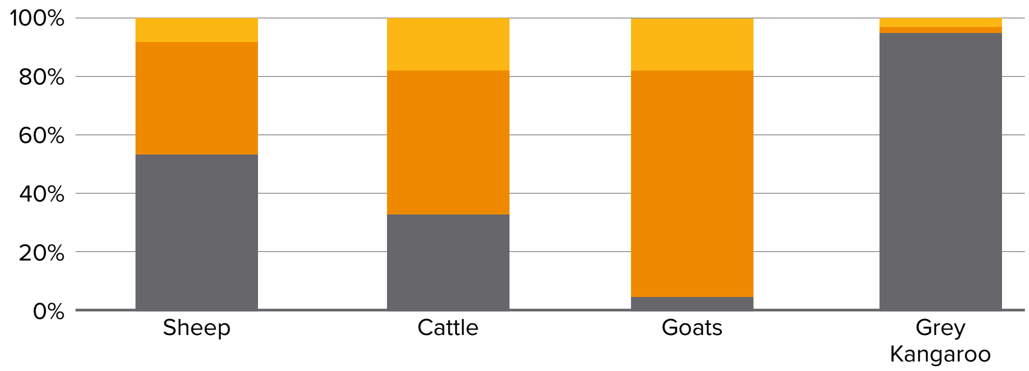


Figure 19: Forbs, browse and grass in the diets of herbivores

Determining the amount of feed available at the end of the growing season, estimating the number of livestock that can be carried over a specified period of time and determining the level of productivity that can be expected from those animals are key components in becoming prudent managers of a pastoral enterprise.

There are several options available for producers to acquire these skills such as Grazing Land Management EDGE courses, Grazing Fundamentals workshops or Nutrition EDGE courses.

For more information refer: mla.com.au/edgenetwork

Pasture intake, pasture quality and diet quality

◆ How does stocking rate influence liveweight gains?

Increasing the numbers of goats in a paddock can increase the liveweight production per hectare, but at what expense? The first and most immediate effect is the reduction of liveweight gain per head.

This response is well documented by research and is well illustrated in Figure 20. The application of principles from this graph to your circumstances can have a large impact on your business.

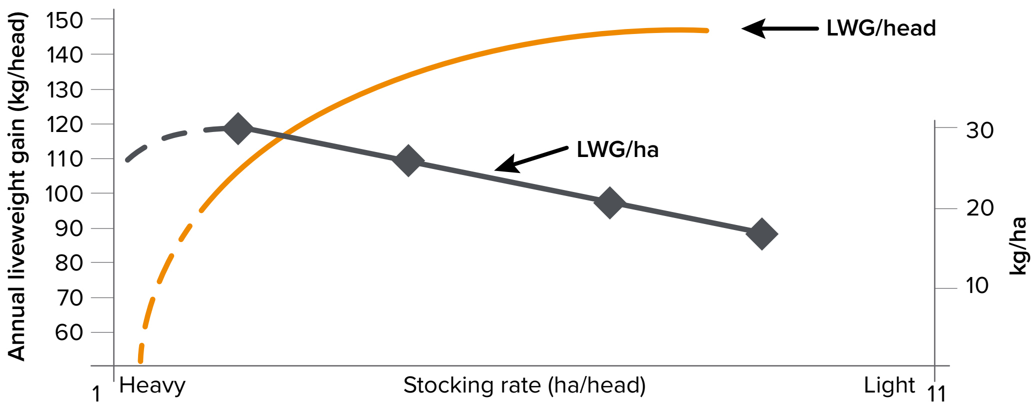


Figure 20: Liveweight gains per head and per hectare as stocking rates are reduced

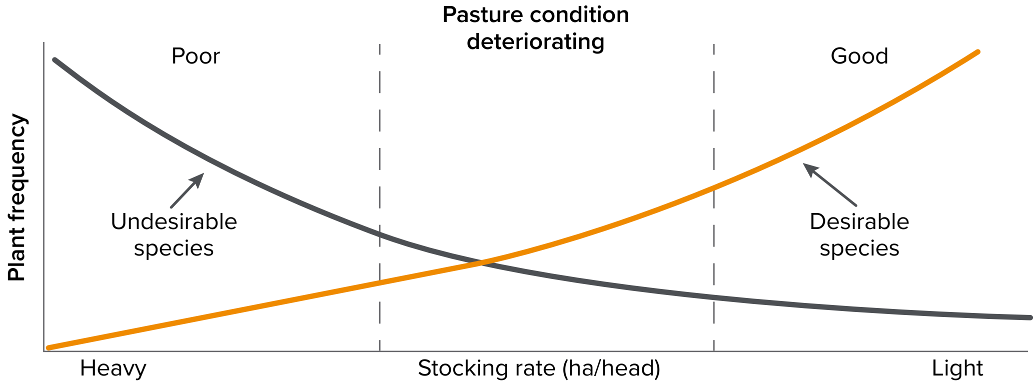


Figure 21: Species composition of pastures as stocking rates change

In Figure 20, as stocking rates are reduced from heavy on the left to lighter towards the right, liveweight gains per head are increased significantly. Halving stocking rates can double liveweight gains per head when initial stocking rates are heavy. As stocking rates are further reduced the increase in liveweight gain becomes progressively less. Reducing stocking rates reduces liveweight gain per hectare.

The other aspect of increased stocking rates is shown in Figure 21. In the long-term, increasing stocking rates from light to heavy reduces desirable pasture species and increases the undesirables, resulting in poor condition pastures.

Finally, stocking rates have a massive impact on worm burdens, as the largest part of any parasite population is actually on the pastures and not in the goat. Increased stocking rates are associated with greater faecal contamination of pastures and more closely cropped pastures. These two factors greatly increase the parasitic challenge.

What utilisation level is best for goats and pastures?

Increasing stocking rate reduces liveweight gain per head. As grazing animals use a higher proportion of pasture, diet quality is reduced as goats are forced to eat poorer quality species and lower quality pasture components such as stem.

Grasses differ in the proportions of leaf and stem they grow. Better pasture species, including perennial, palatable, productive grasses have a high proportion of leaf.

◆ Utilisation

The grazing pressure exerted on pastures over a year can be quantified as the annual pasture utilisation rate.

Annual pasture utilisation is defined as the proportion of the pasture grown over a year (kg/ha) that is eaten by herbivores. For example, 25% annual utilisation means that 25% of the growth in a year (July–June) is eaten. The estimate does not consider any residual left over from the year prior. Generally, utilisation rates of pasture vary from 15–40% depending on rainfall, land type, grazing strategy (especially if regular spelling during the growing season is part of your management) and evenness of forage use both across paddocks and from year to year.

Higher levels of utilisation can be used in wetter coastal areas and on sown pastures, while lower levels are best for infertile soils and drier inland areas.

Managing the utilisation rate on pastures is key to improving land condition and therefore potential pasture growth. Appropriate grazing management ensures the health of pasture species by allowing growth of new leaf, regeneration of root systems and setting of seed. Timing of grazing and resting pastures also assists in achieving a desirable balance between improving land condition while optimising production.

It is important to remember that utilisation relates to the weight of annual pasture grown, not the height of standing feed. The bulk of the weight of perennial grasses is found in the base of the plant in the crown and stem. Figure 22 illustrates how 30% utilisation by weight is markedly different to removing 30% of the height of the plant.

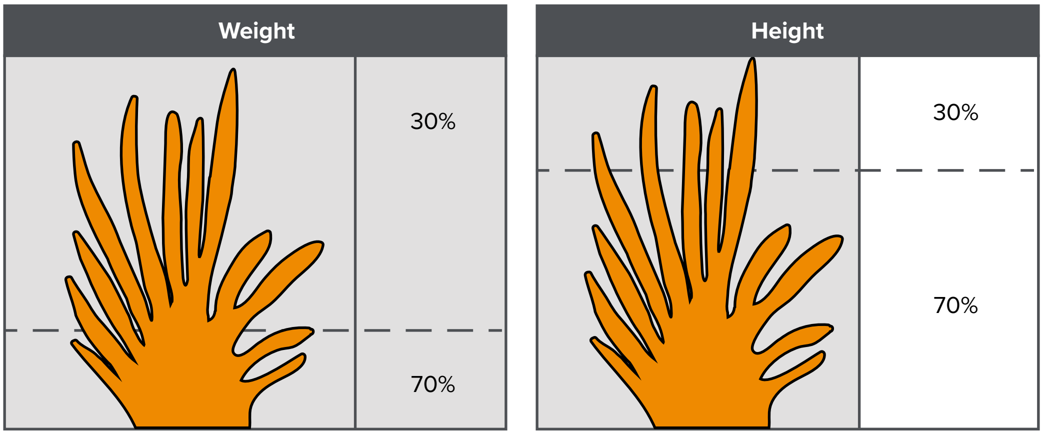


Figure 22: The bulk of the weight of perennial pastures is in the lower portion of the plant in the crown and stem
Source: Forge (1999)

◆ Carrying capacity (CC)

The long-term carrying capacity (LTCC) is the average number of goats that a paddock can be expected to support over five to 10 years, given the mix of land types, their condition, the climate, and given the animal production and land condition objectives.

Current infrastructure development also influences the carrying capacity since grazing efficiency is often reduced as distance to water increases.

Carrying capacity can be estimated over long and short timeframes. The long-term carrying capacity is the average number of animals that a pasture can be expected to support over a long-term planning horizon (five to 10 years or longer) and the short-term carrying capacity is the number of animals that a pasture can support for a set period of time; say a week, month, season or year.

It is important to stick to one timeframe or the other when using carrying capacity figures, as obviously the short-term figures are far more variable than long-term estimates and is usually measured as grazing area (ha) per dry sheep equivalent (DSE).

Stocking Rate refers to the number of animals or DSEs currently grazing an area of land (i.e.

the demand for the available feed). Stocking rate is usually expressed in grazing area (ha) per dry sheep equivalent (DSE) for a nominated period of time. As stocking rate uses the same units as carrying capacity it is important to be clear which figure you are working with at the time.

A pasture or paddock's stocking rate will change with seasonal conditions and animal reproduction, mortalities, transfers in/out and the impact of non-domestic grazers.

◆ Dry matter intake

Intake is the most important factor influencing the level of nutrients supplied to animals. Intake is usually referred to in terms of dry matter (i.e. the non-water component of feed) and is often expressed as a per centage of body weight, e.g. a 40kg goat eating 1kg of dry matter has a dry matter intake of 2.5% of liveweight. Accurate estimating DMI on native pastures is extremely difficult. The amount of pasture goats eat depends on:

- pasture quality
- grazing time
- rate of biting
- size of bites.

The biting rate and grazing time alter very little as the pasture is grazed down; however, the bite size decreases as the quality and availability of feed decreases, thus reducing intake.

When the yield of young lush pasture is greater than 2,000kg DM/ha goats can easily meet their daily intake potential. When the pasture yield is less than 2,000kg DM/ha, bite size decreases. While animals compensate by slightly increasing the time spent grazing, this does not sufficiently compensate for the reduced bite size and so pasture intake declines.

» Plant species differences

Goats can eat larger amounts of herbages and legumes than grasses because they are more readily broken down during chewing and the retention time in the rumen is shorter.

◆ Dry matter

» Dry matter intake

A number of factors influence dry matter intake:

- digestibility
- moisture content
- pasture sward height
- pasture yield
- stage of growth (dry matter, proportion of green leaf and leaf to stem ratio)
- palatability
- pasture contamination (e.g. faeces and plant disease)

- nutrient balance
- stress (e.g. worms, heat, cold, disease, weaning)
- age and class of animal
- milk yield/lactation status
- water quality.

The factor which most impacts on intake is digestibility which is heavily influenced by the fibre content and balance of nutrients in the diet. Low quality diets, e.g. dry winter feed, may only allow intakes of around 1.5% or less of liveweight, while high milk-producing goats on high quality diets, e.g. feedlot rations, may eat up to 5% of liveweight.

Supplementation with urea or a low level of protein supplementation will increase the intake of poor quality, low protein diets by up to 30%.

» Diet selection

Plant factors that affect diet selection include:

1. Palatability
2. Physical characteristics – particle size, resistance to fracture, dry matter content, height and density of sward
3. Chemical characteristics – taste and odour, toxins.

Animal factors that affect diet selection include:

1. Ease of grabbing or biting off feed – animals graze those feeds which they can eat faster
2. Ability to chew and break down plant material
3. Unpleasant sensations, e.g. feeling ill or unsteady, experienced after eating plants, particularly those which may be toxic.

Determining livestock numbers using adult equivalents

◆ Using adult equivalents

Adult equivalent ratings can be used to:

- estimate the potential carrying capacity and therefore income that can be generated from different properties
- make comparisons between livestock enterprises, e.g. compare goats with sheep and cattle
- compare potential carrying capacities when buying land or stocking newly acquired land.

> An AE = the ME requirement of a 450kg *Bos Taurus* steer at maintenance and walking 7km a day – this equates to 72.6 MJ of energy.

A dry sheep equivalent (DSE) is the metabolic energy requirements of a 50kg Merino wether at maintenance and walking 7km/day = 9.44 MJ

An adult 40kg rangeland castrated male goat at maintenance would require 6.7 MJ energy x 1.25 for activity = 8.375 MJ = 0.89 DSE.

Adult equivalent limitations

The adult equivalent methodology can be used to develop long-term carrying capacities and to compare flock or herd structures for different enterprises over longer periods of time. If it is a tool to be used to set stocking rates for particular paddocks, then aspects such as pasture quality, pasture growth rates and utilisation rates need to be considered. Feed intake is directly correlated with pasture quality (digestibility) and this varies significantly during the year.

Table 21: Grazing goats of various weights at maintenance with activity factor of 1.25 expressed in DSE's

	Body weight (kg)					
	20	30	40	50	60	70
Dairy goats						
Male castrates and dry does	0.6	0.9	1.1	1.2	1.4	1.6
Intact males	0.7	1.0	1.2	1.4	1.6	1.8
Meat and indigenous goats						
Male castrates and dry does	0.5	0.7	0.9	1.1	1.2	1.4
Intact males MEm	0.6	0.8	1.0	1.2	1.4	1.6

Forage budgeting

The forage budget is not much different than a normal household budget. It is a matter of determining how much pasture and browse is available and determining how many stock can be safely grazed over a specified period of time, e.g. until the start of the next growing season. It is best carried out at the end of the growing season and should account for any supplements that will be fed.

The first step is to assess the amount of pasture available. Various tools/techniques are available such as:

- cutting randomly selected quadrants along with drying and weighing
- photo standards and calibrating your eye
- Stocktake Plus app
- Stocking rate calculator mla.com.au/stockingrate
- Short how to videos are available here: mla.com.au/goats.

The pasture that is available to stock will include an assessment of the non-edible portion of the feed on offer, the amount lost to trampling, the resudual amount you must leave to avoid degradation and an estimate to include any additonal pasture which may grow over the growing period.

The next step is to determine the total DSE rating for the herd of animals that are to graze the paddock.

Finally, the length of time the herd can safely graze the paddock in question can now be determined. Ideally this calculation ensures that the animals have optimised their productivity and not grazed below the safety residual pasture that was set as a starting point. See Toolkit 7.9 for more details.

◆ Conclusions

- Different classes of stock have vastly different energy and protein requirements.
- Dry matter intake is most significantly affected by the digestibility of pasture.
- Optimum stocking rates maximise liveweight gain and improve the ability of goats to select a good quality diet.
- Forbs and legumes are much more nutritious than tropical grasses.
- Adult equivalents are used to standardise and compare grazing pressure by different classes of stock – refer Fact Sheet 6 for more examples on establishing the DSE ratings for various classes of stock in a herd: mla.com.au/goats.
- Diet quality is used to assess the digestibility and crude protein levels in the diet but it does not account for dry matter intake of pasture.
- Forage budgeting is best carried out at the end of the growing season to determine the number of animals that may be grazed in a paddock, and should account for any supplements that will be fed.
- In the rangelands where browse can become a major component of the diet for goats, an understanding of edible browse species is essential when performing forage budgets and determining stocking rates.

Land condition

Much of the pastoral regions where rangeland goats now graze are in poor condition due to a variety of factors including past overgrazing by a variety of species.

The challenge for goat producers in the rangelands is to ensure the decline in land condition is halted and eventually improved through good grazing management. Understanding land condition is the first step in developing sustainable grazing systems with goats.

At a given point in time, grazing land condition is:

- the capacity of land to respond to rain and produce useful forage
- a measure of how well the grazing ecosystem functions.

Land condition is made up of two components:

1. **Soil condition**
   Soil condition is the capacity of the soil to absorb and store rainfall, to store and cycle nutrients, to provide habitat for seed germination and plant growth, and to resist erosion.
2. **Pasture condition**
   Pasture condition is the capacity of the pasture to capture solar energy and convert it into palatable green leaf, to use rainfall efficiently, to conserve soil condition and to cycle nutrients.

Grazing land degradation means loss of land condition. In the early stages of degradation, land condition responds positively to management changes. Severe degradation is irreversible over a reasonable timescale and/or it is expensive to rehabilitate.

Woodland thickening does not contribute to a land condition score; rather, pasture growth is discounted as tree density increases. Tree density and size is accounted for by measuring tree basal area, which combines the number of trees per hectare with their trunk size or diameter.

◆ The 'ABCD' framework

The 'ABCD' framework is used to classify land condition, adjust pasture growth estimates and provide management options. Land types within a paddock are assessed individually relative to their productive potential. Land types with infertile, shallow soils in 'A' condition will never grow as much pasture as a land type with fertile, deep soils in 'B' condition in the same location, but that doesn't mean it isn't in as good land condition as it possibly can be. The soil and vegetation provide a blueprint for the productive potential of the land type in a particular location (climate). How the land is managed determines if the productive potential of that land is realised or maintained.

The features of different land condition are given below.

» 'A' condition

'A' condition has all the following features:

- good coverage of perennial grasses dominated by the those species considered to be 3P grasses for that land type; little bare ground (<30%) in most years
- few weeds and no significant infestations
- good soil condition, no erosion, good surface condition.

'A' land condition (Image: Robert Karfs)

» 'B' condition

'B' condition has at least one or more of the following, otherwise similar to 'A':

- some decline of 3P grasses; increase in other species (less-favoured grasses, weeds) and/or bare ground (more than 30% but less than 50% in most years)
- some decline in soil condition; some signs of previous erosion and current signs of erosion risk.

'B' land condition (Image: Robert Karfs)

» 'C' condition

Poor or 'C' condition has one or more of the following, otherwise similar to 'B':

- general decline of 3P grasses; large amounts of less-favoured species and/or bare ground (>50% in most years)
- obvious signs of past erosion and/or susceptibility currently high.

'C' land condition (Image: Chris Holloway)

» 'D' condition

'D' condition has one or more of the following features:

- general lack of any perennial grasses or forbs
- severe erosion or scalding, resulting in hostile environment for plant growth

'D' land condition (Image: Robert Karfs)

◆ Pasture stability and resilience

The ease with which land condition can change is best illustrated by representing a ball sitting on an incline.

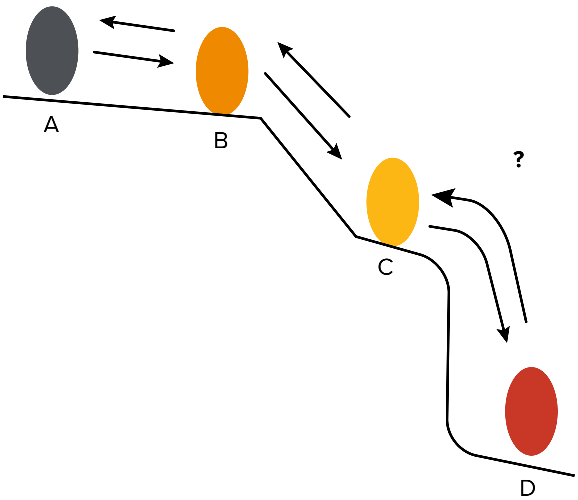


Figure 23: Rolling ball model

Land in condition 'A' is relatively stable. Land that is trending towards 'B' can be fairly quickly reverted to 'A' by a change in management. Land in condition 'B' is susceptible to a quick decline to 'C'. Reversing this change is more difficult, and requires a major change in management and takes time to occur.

Land in 'C' is very susceptible to falling rapidly to condition 'D' and once it is there getting it back is not easy. Improving land condition from 'D' requires more than a simple change in grazing management; it is costly and definitely takes time. It also requires a large input of external energy (e.g. mechanical and/or chemical) and even this may be insufficient; soil condition may be destroyed and beyond recovery.

It is important to distinguish cosmetic changes in land condition from real changes. For example, well-managed grazing land in condition 'A' may appear to change to condition 'B' during a run of dry years, but in reality maintains a good density of perennial plants and quickly resumes the 'classic' look of 'A' condition with one good wet season. Another common misreading of condition is that land in condition 'C' is healthy because it manages to produce green cover during a run of wet years. The reality is that perennial grass density remains low and that, even with some recovery of perennial grasses, soil organic matter and biological activity take much longer to recover.

Land condition is related to stability:

> Stability is a grazing land's ability to persist and retain or recover function after disturbances such as drought, wildfire, overgrazing, or infestation by pests or disease.

Stability is enhanced by:

- improving land condition
- not pushing land so hard that it passes a threshold (a point of no return)
- promoting vegetation diversity.

Key points regarding land conditions

- Land condition reflects the capacity of land to respond to rain and produce useful forage and is a measure of how well the ecosystem is functioning.
- Soil condition and pasture condition are the two key components of land condition.
- The 'ABCD' framework is used to classify land condition.
- Maintaining a high density of perennial grasses is the key to good land condition.
- Recovering land in poor condition requires rest from grazing during the growing season over a number of years. The time required to recover depends on: how degraded the country is; how long the country is rested during the growing season; and the amount and pattern of rainfall during the growing season.

Videos with more information on land condition can be found on the FutureBeef website: futurebeef.com.au/knowledge-centre/glm-related-multimedia-resources

When to spell pastures for the best effect on land condition?

Perennial grasses are dormant during the drier months of the year and draw on energy reserves in the crown and roots for early season growth. If the new shoots are grazed before they can replenish root reserves, more energy is required for the next batch of new shoots, so energy reserves are further depleted. Figure 24 shows how this occurs.

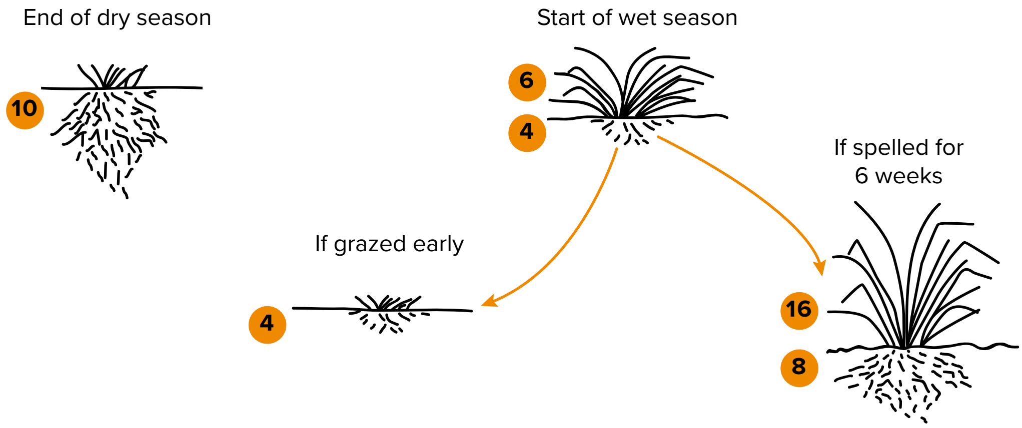


Figure 24: Impact of wet season spelling on plant energy reserves

» Spelling pastures early in the growing season for at least 6–8 weeks is critical for improving land condition.

Usually, full wet season spells are required for a couple of years to improve land condition by one condition class, but other studies show it could take even longer if good seasons are not experienced in that time.

» Spelling to maintain good land condition

Even properties with land in good (A or B) condition can have some patches in poor (C) condition. Maintaining constant stocking rates means the grazing pressure from season-to-season and year-to-year varies with rainfall. In low-rainfall years, stocking pressure and utilisation rates can increase, resulting in the expansion of poor-condition patches. Regular wet season spelling can help to prevent the continuing expansion of these patches.

Spelling each paddock every three to five years allows patches to recover to better condition and reduce the selective patch grazing previously imposed. You don't need complex grazing systems to achieve this. A simple three or four-paddock rotational spelling regime is adequate. *Sustainable management of the Burdekin grazing lands - A technical guide of options for stocking rate management, pasture spelling, infrastructure development and prescribed burning to optimise animal production, profitability, land condition and water quality outcomes*. Copies can be downloaded from the FutureBeef website futurebeef.com.au/knowledge-centre/glm-related-multimedia-resources

» Spelling to recover land from poor to good condition

Recovery of land from poor condition can take a long time and needs good rainfall and growing seasons to work. Spelling pastures from grazing during the wet season and particularly during the early growing season, when grasses are most susceptible to heavy defoliation, will encourage growth of 3P grasses. Rest during the dry season is also useful for maintaining ground cover and improving rainfall infiltration for the next growing season but does little for recovery of summer-growing species.

Supplementation and other tools

Even with the best pasture and grazing management, feed gaps and animal nutritional deficiencies requiring supplementation can occur. Strategic supplementation is used to lift animal performance to meet specific market requirements and promote animal welfare.

Supplementation

There are a range of options for managing nutritional deficiencies. Supplementation is a practical option to address nutritional deficiencies and ensure animals reach production targets.

For the purpose of this module, a supplement is anything fed to goats to supplement what is available in the paddock. This does not refer to full ration feeding in a feedlot.

The following sections provide key information that may influence animal performance.

Responsible supplementation

Supplementation should only be used to supplement existing standing feed. The key is to always monitor pastures closely and ensure a good residual reserve of pasture is maintained so it can respond when the season breaks.

Supplementation can quickly lead to overgrazing and permanent pasture damage if not managed responsibly.

Responses to supplements

Responses to supplements are affected by animal and dietary factors including:

- animal factors
  - physiological status – pregnant, lactating, growing
  - age, liveweight and body composition
  - previous growth performance (compensatory growth)
  - heat and humidity
  - internal parasites
- dietary factors
  - quality and availability of grazed pasture
  - type of supplement and nutrient balance.

» Primary limiting nutrient

Targeting the primary limiting nutrient is the priority for a cost-effective supplementation program.

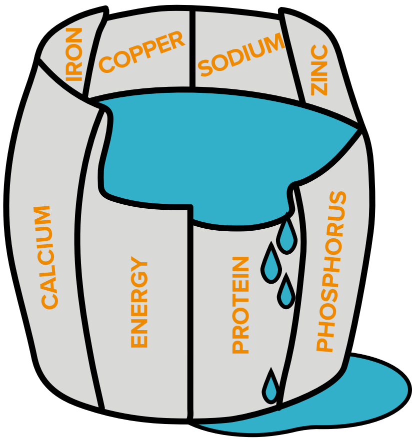


Figure 25: The principle of the primary limiting nutrient. The primary limiting nutrient on the left-hand side is protein. Having fixed the protein deficiency the primary limiting nutrient is now energy on the right-hand side.

» Urea supplementation in various forms

When ample dry feed is available, then provision of a NPN-based supplement is usually the cheapest supplement available, but even this can vary considerably in price depending on the form of supplement used. Price is not the only factor that needs to be be considered. Others include:

- ease of distribution and convenience
- time to prepare and distribute supplement
- quality and control of water points
- infrastructure and mixing equipment.

» Home brews

Depending on the class of goats being supplemented, soil type, region and performance required, the components of a supplement will vary significantly. The aim of most dry season supplementation programs, when protein is the primary limiting nutrient, is to provide about 5g urea/animal/day. The table below provides an indication of the types of recipes that are being used. Salt is usually included to regulate the intake and the amount required will depend largely on the salt content of the goat's diet, including the salt content of the water.

Examples of some dry season lick recipes for breeding animals are:

Table 22: Examples of dry licks containing urea

Ingredient	With phosphorus (kg)			Without phosphorus (kg)		
Salt	75	75	50	100	100	75
Urea	50	50	50	50	50	50
Sulphur	2.5	0	2.5	2.5	0	2.5
Sulphate of ammonia	0	10	0	0	10	0
Kynofos®[1]	25	25	25	0	0	0
CSM[2] or copra meal	0	0	25	0	0	25

1 Used as an example only
2 CSM = cottonseed meal

» Key considerations regarding urea supplementation

1. Ensure there is adequate dry standing feed available.
2. Urea will kill goats if consumed in excessive quantities.
3. After animals are introduced to urea, avoid letting them run out of supplement.
4. Urea should be fed with sulphur at a ratio of around 12:1.
5. Urea supplementation reduces weight loss – it seldom causes weight gain.
6. Supplementation should commence before animals become poor in condition.
7. All loose-mixed urea supplements should be fed in troughs with good drainage.
8. Aim for 5g of urea/day in adults and 3g/day in young goats.
9. Urea supplementation can increase animal feed intakes by up to 30% so adjust stocking rates accordingly.

» M8U (molasses with 8% by weight of urea)

Addition of molasses to the urea usually provides better results as additional energy is being supplied to the animal, however storage and mixing equipment is required and freight can become a major issue depending on the distance from major cane-growing regions.

1. M8U has been widely used in many areas of Queensland to provide energy and protein to poor and weak drought-affected stock and is a very effective supplement for weaners.
2. Additional copra meal can be added to the supplement for very young weaners.
3. M8U is simply molasses with 8% urea. A standard M8U mix is 1,000kg of molasses and 80kg of urea.
4. M8U must be mechanically mixed until the urea is completely dissolved to reduce the risk of toxicity.
5. Molasses is rich in sulphur and so Gran-am or sulphate of ammonia is not required.

» Protein supplementation for growing animals for production

Producers are often confronted with the dilemma of choosing the best nutritional regime to meet targets for growth rates after their animals have been weaned.

Various options exist for ensuring that growing animals will achieve the desired weight to meet market specifications or feedlot entry. These include:

- good quality pastures
- forage crops such as oats and sorghum
- supplementing the existing native pastures with a concentrate feed or protein supplements.

The use of cereal products such as barley and sorghum have been evaluated against feeding protein meals such as cottonseed meal and copra meal in cattle when there is ample roughage available from the pastures. The same research has not been evaluated in goats, but it is suspected the same general relationships apply. Providing there is adequate pasture available, protein meals such as cottonseed meal, copra meal and even palm kernel cake are likely to be much more cost-effective to feed at low inclusion rates, e.g. 0.5% of body weight.

A spreadsheet calculator was developed for cattle as a simple first-step tool to assess the relative costs of feeding two different types of supplement for increased cattle growth: the protein meals which have medium to high protein content and often also have relatively high-energy (M/D; MJ/kg DM) content; and the 'energy sources', which are high in energy but usually much lower in protein content. It should be remembered the 'energy sources' do contribute to the protein nutrition of the animal by virtue of their stimulation of microbial protein production in the rumen.

In general, the growth response to increasing intakes of the 'energy sources' was linear, regardless of type. By contrast, in most cases the response per unit intake of meal was greatest at low intakes of meal and declined as intake increased.

In the example illustrated below, suppose the goal is to achieve a growth rate of 0.5kg liveweight per day and the options are to feed grain or concentrate valued at $280/tonne or a protein meal valued at $400/tonne.

NB: Adequate dry feed must be available for both options.

Steer liveweight	350kg
Additional growth required	0.5kg/day
Supplement cost	
Protein meal	$400/tonne
Energy source	$280/tonne

	Protein meal	Energy source
Cost of supp (c/kg)	40.0	28.0
Intake supp. required (kg/d)	1.25	3.37
Cost (c/d)	**50.1**	**94.5**
Cost (c/kg extra gain)	**100.3**	**189.0**

Figure 26: A screen shot from the least cost supplement calculator showing relative costs of gain

The calculator demonstrates that it will cost 50.1 cents/day for the protein supplement compared to 94.5 cents/day for the concentrate at growth rates of 0.5kg/day. Alternatively, it shows that it will cost $1 to put on each additional kilogram using the protein supplement compared to $1.89 using the grain/concentrate for 350kg steers growing at 0.5kg per day. It is only when growth rates greater than 1kg/day are required, that the protein supplement becomes more expensive than the grain option at the prices listed above.

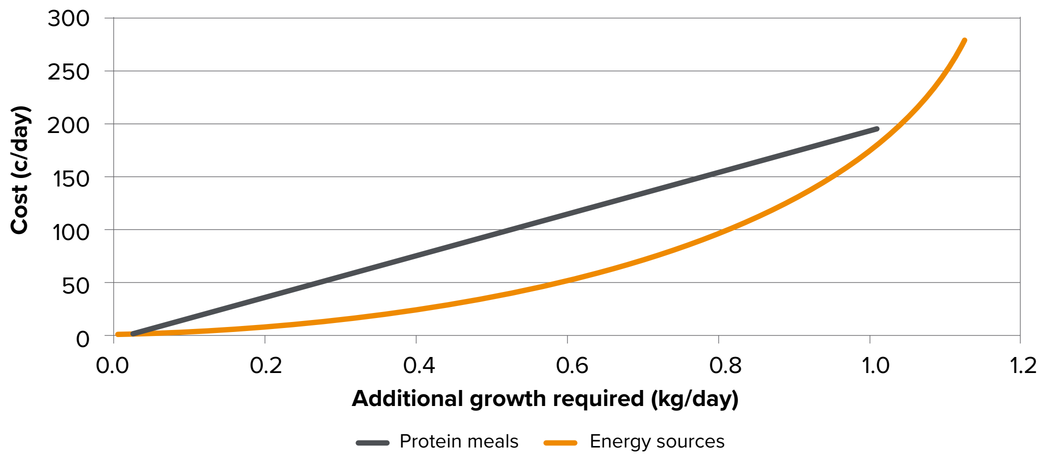


Figure 27: Output graph from least cost supplement calculator

Grain and protein supplement prices fluctuate markedly depending on availability and season. This calculator allows producers to make informed decisions on the best supplement option to feed. The tool is not yet available for goats, but the same general relationships will most likely exist.

For growing goats at moderate growth rates, it may be far more cost-effective to provide a protein supplement than to provide grain or a concentrate. In the cotton-growing regions and in the central west of NSW and Victoria, whole cottonseed, cottonseed meal and lupins would appear to be very attractive options for backgrounding operations.

The responses of goats fed protein meals and/or lupins during the autumn and winter months due to 'winter stasis' is largely unknown, but it would be safe to assume the cost–benefits would be less and therefore caution is required when developing budgets for autumn feeding programs.

» Interaction between supplement and pasture

If pasture intake is reduced when supplementing stock, this is a substitution effect on intake. Whether the effect is associative or substitution depends on:

- supplement type
- pasture quality
- level of feeding.

Associative supplementation occurs when animals are supplemented at low levels with nutrients which are limiting, e.g. rumen degradable protein such as urea.

Substitutional supplementation usually occurs with higher supplement intakes and is more pronounced on high quality pastures.

» Effect of supplement on pasture and total dry matter intake

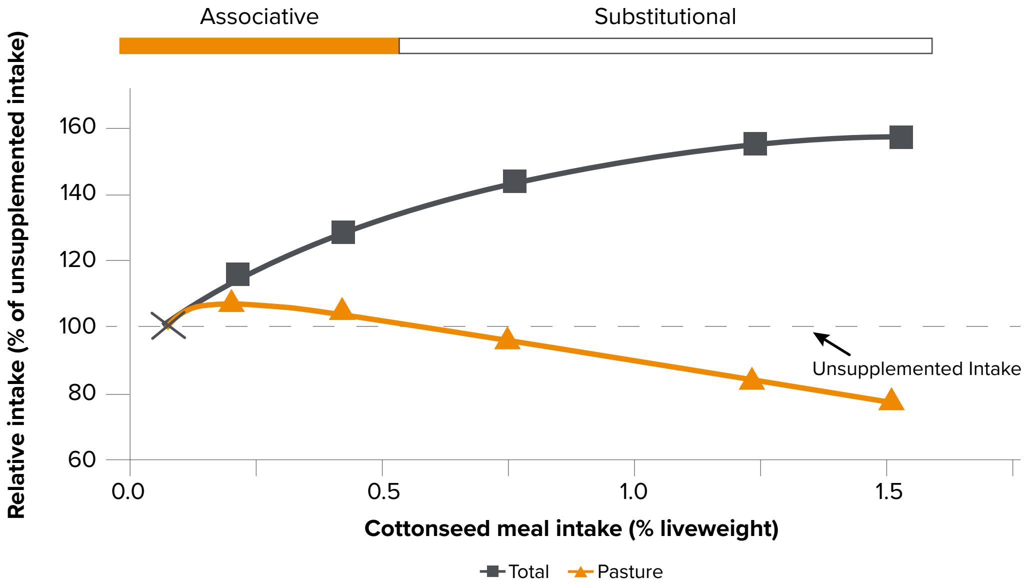


Figure 28: Effect of supplement on pasture and total dry matter intake
Source: McLennan (1997)

» Compensatory growth

Compensatory growth is the better than expected growth performance seen in animals following a period of very low weight gain or weight loss. Compensation can be nil, partial or complete in the recovery period.

The extent of compensatory growth is influenced by:

- age of the animal – younger animals show stronger compensatory growth than older animals
- severity and length of the restriction – the longer the period of restriction, the less likely it is that animals will compensate
- condition of animals when they are restricted – if they are in poor condition, their recovery will range from nil to very poor
- quality of feed after the period of restriction.

Compensatory growth works through a combination of reduced maintenance requirements, increased efficiency of growth, increased protein deposition and increased appetite resulting in increased feed intake.

Most of the compensation occurs in the first two months once re-feeding begins. There are no 'hard and fast' rules to predict compensatory growth. Just be aware that it exists and, if it occurs, it is a bonus.

Compensatory gain may negate the benefits of supplementation or provide a bonus weight gain. While most of the research has been done in cattle and sheep, similar results have been observed in goats.

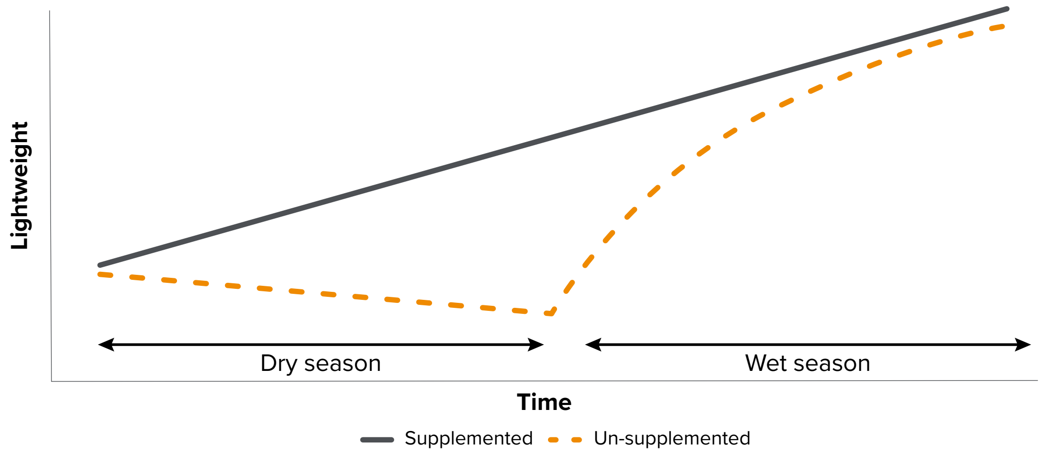


Figure 29: Example of compensatory growth
Source: McLennan unpublished in Bowen et al. 2015

» Feed additives (rumen modifiers)

'Rumen modifiers' includes anything that modifies the rumen environment or the population of microorganisms in the rumen. Rumen modifiers modify the fermentation process in the rumen by changing the microbial population, i.e. they change the rumen environment or microorganism population.

Rumen modifiers improve feed conversion efficiency. Therefore, at the same level of feed intake, animal production will be improved.

Rumen modifiers increase propionic acid production, whilst at the same time reducing gas production. They reduce the proportion of dietary protein degraded and also reduce microbial protein synthesis, which increases the amount of bypass protein available. Degradation of dietary protein is reduced, increasing the flow of protein to the small intestine. This is only beneficial to the animal if the rumen ammonia level is high enough in the diet.

There is no benefit if the protein concentration in the diet is low. Rumen modifiers also reduce the proportion of absorbed amino acids for energy production, enabling more amino acids to be used for protein (e.g. muscle gain).

Rumen modifiers are also known as ionophores and include monensin, lasalocid, salinomycin, narasin and tetronasin. Rumen modifiers like Rumensin® and Bovatec® are not currently registered for goats and a veterinary prescription would be required. They usually only work when animals are gaining weight at a reasonable rate. Generally speaking, the increase in weight gain from using rumen modifiers is approximately 10%. Rumen modifiers don't alter the composition of weight gain. The benefits of using ionophores is markedly reduced when animals are achieving high weight gains, most likely due to the significantly higher level of propionic acid produced. There is no advantage in using rumen modifiers when animals are losing or are only slightly gaining weight.

Rumen modifiers are also commonly used to control coccidiosis in young weaner goats and also for bloat control under veterinary supervision. It is important to always follow recommended dose rates, as high levels are toxic. Antibiotics and ionophores are prohibited in some branded supply chains.

Some rumen modifiers are unpalatable and, when mixed with a supplement, can reduce supplement intake. This can be used in a practical sense to help regulate supplement intake. They are often included in palatable, fortified molasses mixes as a means to control intake.

◆ Reading a label

Table 23: An example of a feed label that may be seen accompanying a bag of loose-lick supplement

Analysis	
Total crude protein	30%
Equivalent crude protein	23%
Total protein	7%
Urea	8%
Calcium	8%
Phosphorus	4%
Salt	2%
Sulphur	2%
Copper	300mg/kg
Iodine	30mg/kg
Zinc	500kg

Often, a supplement is given a name that reflects the class of stock, nutritional deficiency or type of country the livestock are running on. The supplement name is not, however, the most effective way to objectively assess its suitability. It is more important to become familiar with the nutrient profile on the label.

By law, all supplements that contain urea must list urea as an ingredient. There is no requirement to list all of the other ingredients in a supplement, so the nutrient analysis contains nutrient levels and does not relate them back to the ingredients.

All goat producers also need to be aware of the legislation regarding the feeding of restricted animal material (RAM). RAM is defined as any material taken from a vertebrate animal other than tallow, gelatin, milk products or oils. It includes rendered products, such as blood meal, meat meal, meat and bone meal, fish meal, poultry meal and feather meal, and compounded feeds made from these products. Australia's enforceable bans on the feeding of RAM to ruminant animals are part of a comprehensive national transmissible spongiform encephalopathy (TSE) Freedom Assurance Project. For more information refer to animalhealthaustralia.com.au

» There are three components of protein listed on a label

1. Crude protein

The crude protein level is the protein that comes from organic sources, or 'true protein'. This includes the protein in any protein meals or grains that are included in the supplement.

Example:
Copra meal included in a lick at 20%, and it has a 20% crude protein level

1,000 grams x 0.20 = 200 grams of copra meal x 0.20 = 4% crude protein

2. Equivalent crude protein

Equivalent crude protein is not a true protein source, but a calculated equivalent amount of protein based on the nitrogen level in non-protein nitrogen sources such as urea and sulphate of ammonia.

Example:
If the urea content in a lick is 30% and the sulphate of ammonia content is 6%, then the crude protein equivalent is calculated as follows:

Urea has a 287% crude protein equivalent

Sulphate of ammonia has a 126% crude protein equivalent

Therefore, if the lick contains 30% urea and 6% sulphate of ammonia, then:

- urea 30% x 2.87 = 86.1
- sulphate of ammonia 6% x 1.26 = 7.56
- equivalent crude protein (in the lick) = 93.66

3. Total protein (or total crude protein)

Total protein or total crude protein is the sum of the crude protein and equivalent crude protein levels.

4. Urea equivalent

Most companies will not show the sulphate of ammonia level on a label. Instead, the sulphate of ammonia level will be listed as 'urea equivalent' level, which is the ammonia contribution from both urea and sulphate of ammonia. This is calculated as follows:

Sulphate of ammonia level – let's say it is 8% in a supplement, then:

- 8% multiplied by 1.26 (crude protein equivalent) = 10.08%
- 10.08% divided by 2.87 (crude protein equivalent for urea) = 3.51% urea equivalent from sulphate of ammonia.

This is added to whatever the urea level is in the supplement then the total urea equivalent is multiplied by 2.87 to give a crude protein equivalent level.

This is extremely important to calculate for licks that are high in both urea and sulphate of ammonia. A lick that is high in sulphate of ammonia can significantly increase the total urea content of a lick, making it either very bitter, or extremely toxic if consumed in significant quantities.

» Supplement types

The levels of each nutrient and the intake recommendations are generally two good indications of whether a supplement is an energy or protein or protein-mineral supplement, however this is not always the case, so it is important to find out more if you're uncertain.

In some cases it may be necessary and more cost-effective to combine supplements, e.g. urea and molasses, to increase both protein and energy in the diet.

Table 24: Examples of different supplement types

Protein only	Protein (some energy)	Energy (some protein)	Energy only	Protein and minerals
Urea	Protein meals • copra • cottonseed • soybean	Grain	Molasses	Commercial • blocks • loose mixes • liquids
	Whole cottonseed			

Source: futurebeef.com.au/planning-and-managing-a-supplementary-feeding-program

Once you've determined the nutrients that are limiting production, you can select which type of supplements your animals need based on:

- cost
- availability
- palatability
- ease of feeding
- time needed to prepare and distribute
- equipment (and skill) required to prepare and feed out
- convenience.

» Protein supplements

Feeding stock protein supplements provides nitrogen and sulphur for the development of large, healthy populations of rumen microorganisms. This increases the rate of digestion which increases the amount of grass eaten which improves animal performance. There are two broad categories of protein fed to ruminants:

1. Rumen degraded protein – protein that is broken down in the rumen by the rumen microorganisms to make microbial protein. These microorganisms are subsequently flushed out of the rumen and are digested along with bypass protein further along the digestive system.
2. Undegraded dietary protein – protein that escapes breakdown in the rumen and is digested in the abomasum and small intestines, similar to microbial protein.

Protein meals like cottonseed, copra and canola are common sources of rumen degradable protein, bypass protein and energy. Unlike protein meals, urea contains no energy or bypass protein, but when it's fed to ruminants in association with sulphur it can be used by rumen microorganisms to improve rumen function and supply a source of microbial protein.

When there is plenty of dry feed available, feeding a non-protein nitrogen-based supplement is usually the cheapest option, however this may not always be the case.

More information about supplementary feeding, including feeding urea, is available from the FutureBeef website and in *Weaner management in northern beef herds* and *Water medication: a guide for beef producers* available from Meat & Livestock Australia.

» Energy supplements

Energy supplements are eaten in larger quantities. Often the feeding recommendations are expressed on a per centage of body weight, or significant intake levels. Energy supplements also usually indicate the energy content, which is significant. There are some supplements that list the energy level but it may be quite low or the intake recommendation is so low that the amount of energy eaten is negligible.

It is important to calculate how much energy your livestock are likely to realistically and practically receive from a supplement.

Acronyms

ADG	average daily gain
ADF	acid detergent fibre
AE	adult equivalent
BMR	base metabolic rate
BW	body weight
CC	carrying capacity
CHO	carbohydrate
CO_2	carbon dioxide
CP	crude protein
d	day
DE	digestible energy
dg	degradability
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
DOM	digestible organic matter
DS	dietary salt
DSE	dry sheep equivalent
EBIT	earnings before interest and tax
EC	electrical conductivity
eNDF	effective neutral detergent fibre
FCE	feed conversion efficiency
FCR	feed conversion ratio
FFA	free fatty acids
FNIRS	faecal near infra-red reflectance spectroscopy
GE	gross energy
GP	grazing pressure
H_2O	water
HGP	hormone growth promotant
LAI	leaf area index
LW	liveweight
LWG	liveweight gain
M8U	a mixture of molasses and 8% urea (it is essential to use a mechanical mixer)
MCP	microbial crude protein
ME	metabolisable energy
MJ	megajoule
MP	microbial protein or metabolisable protein
MT	maximum temperature
MUP	molasses with added urea and protein meal
NDF	neutral detergent fibre
NE	net energy
NE_m	net energy for maintenance
NE_g	net energy for growth
NE_l	net energy for lactation
NIRS	near infra-red reflectance spectroscopy
NPN	non-protein nitrogen
PEM	polioencephalomalacia
PiP	plasma inorganic phosphorus
PP	precipitation
ppm	parts per million
RDN	rumen degraded nitrogen
RDP	rumen degraded protein
RUE	rainfall use efficiency
TDS	total dissolved solids
TSS	total soluble salts
UDP	undegraded protein
VFA	volatile fatty acid

Glossary

3P grasses – Grasses that are perennial, palatable and productive.

Abomasum – True gastric stomach (fourth stomach) where chemical digestion occurs.

Acetic acid – One of the essential volatile fatty acids derived from fermentation in the rumen.

Adult equivalent (AE) – A system that enables comparison of dry matter intakes of livestock (usually cattle) adjusting for weight and metabolic state.

Amino acids – The building blocks from which proteins are formed containing carbon, oxygen, nitrogen, hydrogen, and some sulphur and phosphorus.

Annual plant – A plant that completes its life cycle within a single year from seed.

Butyric acid – One of the essential volatile fatty acids derived from fermentation in the rumen.

Carbohydrates (CHOs) – A group of organic compounds containing carbon, hydrogen and oxygen found in plants and animals, and includes simple sugars, starch and cellulose. Carbohydrates are metabolised to produce energy.

Carrying capacity (CC) – The average number of stock per unit area that can be supported in the long-term (five to 10 years).

Crude protein (CP) – The protein content of a substance based on the measured nitrogen content multiplied by 6.25.

Crude protein equivalent (CPE) – Protein equivalent that comes from non-protein nitrogen sources such as urea and/or sulphate of ammonia.

Decreaser species – More desirable plant species, generally perennial, which decrease in frequency with increased grazing pressure.

Digestibility – The proportion of the feed consumed that is digested by the animal, usually expressed as a per centage.

Digestible energy (DE) – Energy component of feed available after digestion; measure of energy in a feed that is available to monogastrics such as horses, chickens and pigs.

Digestible organic matter (DOM) – Per centage of the non-mineral component of the diet that is digestible.

Dry matter (DM) – Component of feed left after drying when all the moisture is removed; expressed as a per centage.

Dry matter digestibility (DMD) – Level of digestibility on a dry matter basis expressed as a per centage.

Dry sheep equivalent (DSE) – A system that allows comparison of dry matter intakes of livestock (usually sheep) adjusting for weight and metabolic state.

Energy – The capacity of food to provide the fuel for all the processes an animal will perform including maintenance, growth, milk production and work. Measured in megajoules (MJ).

Fats and lipids – A group of compounds containing carbon, hydrogen and oxygen found in plants and animals. Fats and lipids are important sources of energy, being more energy dense than carbohydrates.

Feed conversion ratio (FCR) – Ratio of animal liveweight gain to amount (kg) of dry matter consumed.

Forbs – Small broadleaf plants (not grasses), often called weeds or herbage.

Grazing pressure (GP) – Grazing pressure is the relationship between feed on offer and total stock demands (including native and feral animals), with stock preferences causing more or less pressure on some areas or on some plant species in a pasture.

Gross energy (GE) – Total energy component of the diet that does not account for what is not available for absorption by the animal.

Ground cover – The proportion of the soil surface that is covered by grass, herbage, litter and manure, usually expressed as a per centage.

Gut fill – The amount of an animal's total liveweight that is composed of its stomach contents.

Increaser species – Less-desirable plant species, often short-lived, which increase in frequency with increased grazing pressure, or reduced pasture condition.

Indicator species – Plants whose presence (or absence) and frequency indicate something about the condition of the pasture.

Infiltration – The amount of rainfall that goes into the soil, and is not lost to runoff or evaporation.

Intake – The amount of dry matter eaten by an animal, often expressed as a per centage of bodyweight.

Intermediate species – Species that do not reliably indicate pasture condition but may be important for goat production, depending upon the situation.

International units – An international system for measuring biochemical compounds (e.g. vitamins).

Lignin – A complex aromatic compound present in large quantities in wood, hulls and straw. This is the indigestible component of plants.

Liveweight (LW) – The animal's weight.

Liveweight gain (LWG) – The gain of liveweight since last measurement.

Macro-minerals – Minerals required in quantities measured in grams per day (g/day). Also referred to as major minerals.

Megajoules (MJ) – Megajoules are the units in which energy is measured.

Metabolisable energy (ME) – The part of dietary energy remaining after losses to faeces, urine and rumen gases.

Microbial crude protein (MCP) – Protein produced by rumen microorganisms.

Micro-minerals – Minerals required in quantities measured in milligrams per day (mg/day). Also referred to as trace minerals.

Net energy (NE) – The proportion of dietary energy that is used by the animals, for maintenance, growth and lactation. This measurement is not generally used in Australia.

Near infra-red reflectance spectrometry (NIRS) – An analytical tool for estimating feed quality.

NIRS – see near infra-red reflectance spectrometry.

Non-protein nitrogen (NPN) – Nitrogen not derived from protein.

Non-structural carbohydrates – Soluble sugars such as glucose, sucrose and starch found within plant cells and not in the cell walls.

Oesophageal groove – Muscular folds in the reticulum which, when closed, allow food to pass directly from the oesophagus into the omasum. When open, food falls into the rumen and reticulum. The closing action is stimulated through suckling.

Omasal orifice – An opening leading from the reticulum to the omasum.

Organic matter (OM) – Chemical compounds derived from living organisms.

Pasture composition – The mix of plant species in a pasture, with each species usually being expressed as a per centage by weight or by frequency.

Pasture utilisation – The amount of a pasture used by grazing animals usually expressed as a per centage of total pasture biomass grown in one season.

Pasture yield – The total amount of pasture at any given time, usually expressed as kilograms of dry matter per hectare (kg DM/ha).

Perennial plant – Plant having a life cycle of more than one growing season.

pH – A measure of the hydrogen ion concentration. The lower the pH, the more acidic the solution or compound and the higher the pH, the more basic or alkaline the solution.

Photographic standard – A series of photographs of different yields of pastures, which are used to help determine pasture yield in the paddock.

Photosynthesis – The process by which plants capture solar energy in green leaves and convert light energy into chemical energy.

ppm (parts per million) – An international unit for measuring trace minerals. It is equivalent to milligrams per kilogram (mg/kg).

Primary limiting nutrient – Nutrient which is most limiting production.

Propionic acid – One of the essential volatile fatty acids derived from fermentation in the digestive tract.

Protein – see Crude protein.

Rumen – Second chamber of the 'stomach'; the main place for digestion in ruminants.

Rumen degraded protein (RDP) – The proportion of crude protein degraded in the rumen, or 'bypass' protein.

Rumen microorganisms – Simple organisms found in the rumen and reticulum.

Senescence – Growth phase of a plant from full maturity to death.

Standing feed – The total amount of pasture at any given time, usually expressed as kilograms of dry matter per hectare (kg DM/ha).

Stocking rate (SR) – The number of livestock per unit area at a given time.

Structural carbohydrates – Complex carbohydrates (cellulose and hemi-cellulose) found in plant cell walls that maintain the plant's structure.

Trace minerals – Minerals required in quantities measured in milligrams per day (mg/day). Also referred to as micro-minerals.

True protein – Protein found in plant and animal tissue.

Undegraded dietary protein (UDP) – Proportion of crude protein not degraded in the rumen.

Volatile fatty acids (VFAs) – Acids produced in the rumen through the digestion of feeds. The main volatile fatty acids are acetic, propionic and butyric.

Water holding capacity of soils – The quantity of water (measured in millimetres of rainfall) a soil can hold before the water begins to drain from the soil profile.

Wilting point – The point below which plants cannot extract moisture from the soil.

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Toolkit 7 – Nutrition

Tool 7.1 – Finding further information

Tool 7.2 – Intakes of pen-fed goats

Tool 7.3 – Edible shrubs and forbs

Tool 7.4 – Nutritional disorders

Tool 7.5 – Toxic plants

Tool 7.6 – Safe upper limits for substances possibly contained in water for livestock

Tool 7.7 – Palatability of plants commonly eaten by goats

Tool 7.8 – Feedlotting goats

Tool 7.9 – Forage budgeting

Tool 7.10 – Recommendations for energy requirements for goats

Tool 7.11 – Metabolic protein requirements

Tool 7.12 – Composition of some common forages

Tool 7.13 – High-energy feeds

Tool 7.14 – Medium-energy feeds

Tool 7.15 – Low-energy-density feeds (sources of fibre and dry matter)

Tool 7.16 – High-protein feed sources

Tool 7.17 – How to calculate the required energy supplement

Tool 7.1 – Finding further information

◆ Courses, tools and workshops

- Low Stress Stockhandling: lss.net.au
- Goat husbandry courses: go to dpi.nsw.gov.au and search 'goat care and management'.
- MLA events: mla.com.au/events
- EDGE Network courses: learning about grazing strategies and nutrition. Go to mla.com.au/edgenetwork
- PROGRAZE®: is a pasture course for temperate pasture areas. Go to dpi.nsw.gov.au and search 'prograze'
- Stocktake – learning to better manage feed availability in rangeland areas: stocktakeplus.com.au
- MLA Stocking rate calculator: mla.com.au/stockingrate
- MLA Feed demand calculator: mla.com.au/feeddemand
- MLA Rainfall to Pasture Growth tool: mla.com.au/tools and select Pasture Tools and Calculators. Click the first option.
- *Understanding your stocking rate and feed supply demand profile*. Go to evergraze.com.au and search 'stocking rate feed supply demand'. Select final option.
- *Regional pasture growth rates.* Go to evergraze.com.au and search 'regional pasture growth rates'. Select option second from the bottom.

◆ Websites

Videos, resources and fact sheets relating to nutrition and general goat enterprise management:

- MLA: mla.com.au

Information and videos on nutrition, forage budgeting and paddock management:

- futurebeef.com.au

Use of chemicals including minor use permits and withholding periods for chemical treatments:

- Australian Pesticides and Veterinary Medicines Authority (APVMA) – apvma.gov.au

Export of live animals:

- LiveCorp – livecorp.com.au
- Australian Livestock Exporters' Council – auslivestockexport.com

Animal health issues:

- Animal Health Australia – animalhealthaustralia.com.au

Biosecurity issues:

- Farm Biosecurity – farmbiosecurity.com.au

Red meat processing and export:

- Australian Red Meat Exporters – australianredmeatexporters.mla.com.au
- SAFEMEAT – safemeat.com.au

National Livestock Identification System:

- NLIS – nlis.com.au

Goat industry representation and information

- Goat Industry Council of Australia – gica.com.au

General information

- AgriFutures Australia – agrifutures.com.au

State and territory departments of primary industries and agriculture:

- NSW Department of Primary Industries – www.dpi.nsw.gov.au/
- NSW Department of Industry – industry.nsw.gov.au
- South Australian Research and Development Institute – sardi.sa.gov.au
- Primary Industries and Regions South Australia – pir.sa.gov.au
- Department of Primary Industries and Regional Development – agric.wa.gov.au
- Queensland Department of Agriculture and Fisheries – daf.qld.gov.au
- Northern Territory Government – nt.gov.au/industry/agriculture
- Department of Primary Industries, Parks, Water and Environment – dpipwe.tas.gov.au
- Department of Economic Development, Jobs, Transport and Resources – agriculture.vic.gov.au

Tool 7.2 – Intakes of pen-fed goats

Estimates of voluntary DM intake (kg/day) by growing goats in a pen or stall environment

MEC (MJ/kg)	ADG (g/day)	BW (kg)									
		10	15	20	25	30	35	40	45	50	55
Dairy goats[a]											
7	0	0.14	0.61	0.75	0.89	1.02	1.15	1.27	1.39	1.50	1.61
	50	0.50	0.69	0.85	0.99	1.13	1.25	1.38	1.49	1.61	1.72
	100		0.75	0.94	1.09	1.23	1.36	1.48	1.60	1.71	1.82
	150			1.00	1.17	1.32	1.45	1.58	1.70	1.81	1.92
9	0	0.37	0.50	0.62	0.73	0.84	0.95	1.05	1.14	1.24	1.33
	50	0.42	0.58	0.72	0.84	0.95	1.05	1.15	1.25	1.34	1.43
	100	0.43	0.65	0.80	0.93	1.05	1.15	1.25	1.35	1.45	1.54
	150	0.40	0.69	0.87	1.01	1.14	1.25	1.35	1.45	1.55	1.64
	200		0.71	0.93	1.09	1.22	1.34	1.44	1.55	1.64	1.73
	250			0.97	1.15	1.30	1.42	1.53	1.64	1.73	1.83
	300			1.00	1.21	1.36	1.50	1.61	1.72	1.82	1.92
11	0	0.32	0.43	0.53	0.63	0.73	0.82	0.90	0.99	1.07	1.15
	50	0.37	0.51	0.63	0.74	0.83	0.92	1.01	1.09	1.17	1.25
	100	0.38	0.58	0.72	0.83	0.93	1.02	1.11	1.20	1.28	1.36
	150	0.35	0.62	0.79	0.91	1.02	1.12	1.21	1.29	1.38	1.46
	200		0.64	0.84	0.99	1.10	1.21	1.30	1.39	1.47	1.55
	250			0.89	1.05	1.18	1.29	1.39	1.48	1.56	1.65
	300			0.92	1.10	1.25	1.37	1.47	1.57	1.65	1.74
13	0	0.28	0.38	0.48	0.56	0.65	0.73	0.80	0.88	0.95	1.02
	50	0.33	0.47	0.57	0.67	0.75	0.83	0.91	0.99	1.06	1.13
	100	0.34	0.53	0.66	0.76	0.85	0.93	1.01	1.09	1.16	1.23
	150	0.31	0.57	0.73	0.84	0.94	1.03	1.11	1.19	1.26	1.33
	200		0.59	0.78	0.92	1.02	1.17	1.20	1.28	1.36	1.43
	250			0.83	0.98	1.10	1.20	1.29	1.37	1.45	1.52
	300			0.86	1.03	1.17	1.28	1.37	1.46	1.54	1.61
Indigenous goats[a]											
7	0	0.38	0.51	0.63	0.75	0.86	0.97	1.07	1.17	1.27	1.36
	50	0.41	0.58	0.72	0.84	0.96	1.06	1.17	1.26	1.36	1.45
	100		0.64	0.79	0.93	1.04	1.15	1.26	1.36	1.45	1.55
	150			0.85	1.00	1.12	1.24	1.34	1.45	1.54	1.64
9	0	0.31	0.42	0.52	0.62	0.71	0.80	0.88	0.96	1.04	1.12
	50	0.35	0.49	0.61	0.71	0.80	0.89	0.98	1.06	1.14	1.21
	100	0.35	0.55	0.68	0.79	0.89	0.98	1.07	1.15	1.23	1.31
	150	0.31	0.58	0.74	0.87	0.97	1.07	1.15	1.24	1.32	1.40
	200		0.59	0.79	0.93	1.04	1.14	1.24	1.32	1.40	1.48
	250			0.82	0.98	1.11	1.22	1.31	1.40	1.49	1.57
11	0	0.27	0.36	0.45	0.53	0.61	0.69	0.76	0.83	0.90	0.97
	50	0.30	0.44	0.54	0.63	0.71	0.78	0.86	0.93	1.00	1.06
	100	0.30	0.49	0.61	0.71	0.79	0.87	0.95	1.02	1.09	1.15
	150	0.26	0.52	0.67	0.78	0.87	0.96	1.03	1.11	1.18	1.24
	200		0.53	0.72	0.84	0.95	1.03	1.12	1.19	1.26	1.33
	250			0.75	0.90	1.01	1.11	1.19	1.27	1.34	1.41
13	0	0.24	0.32	0.40	0.47	0.54	0.61	0.68	0.74	0.80	0.86
	50	0.27	0.40	0.49	0.57	0.64	0.71	0.77	0.84	0.90	0.96
	100	0.27	0.45	0.56	0.65	0.73	0.80	0.86	0.93	0.99	1.05
	150	0.23	0.48	0.62	0.72	0.81	0.88	0.95	1.02	1.08	1.14
	200		0.49	0.67	0.78	0.88	0.96	1.03	1.10	1.16	1.22
	250			0.70	0.84	0.94	1.03	1.11	1.18	1.24	1.31

a:
Meat = ≥ 50% Boer;
Dairy = Saanen, Alpine, Damascus, Norwegian, Swedish Landrace and dairy crossbreed;
Indigenous = neither
meat nor dairy, not including Angora.

Estimates of voluntary DM intake (kg/day) by growing goats in a pen or stall environment

MEC (MJ/kg)	ADG (g/day)	BW (kg)									
		10	15	20	25	30	35	40	45	50	55
Meat goats[a]											
7	0	0.38	0.51	0.63	0.75	0.86	0.97	1.07	1.17	1.27	1.36
	50	0.42	0.60	0.73	0.85	0.97	1.07	1.18	1.28	1.37	1.47
	100		0.66	0.82	0.95	1.07	1.18	1.28	1.38	1.48	1.57
	150			0.89	1.03	1.16	1.27	1.38	1.48	1.57	1.67
9	0	0.31	0.42	0.52	0.62	0.71	0.80	0.88	0.96	1.04	1.12
	50	0.36	0.50	0.62	0.72	0.81	0.90	0.99	1.07	1.15	1.23
	100	0.37	0.57	0.70	0.81	0.91	1.00	1.09	1.17	1.25	1.33
	150	0.34	0.61	0.77	0.90	1.00	1.10	1.19	1.27	1.35	1.43
	200		0.63	0.83	0.97	1.09	1.19	1.28	1.37	1.45	1.53
	250			0.87	1.04	1.16	1.27	1.37	1.46	1.54	1.62
	300			0.90	1.09	1.23	1.35	1.45	1.54	1.63	1.71
11	0	0.27	0.36	0.45	0.53	0.61	0.69	0.76	0.83	0.90	0.97
	50	0.31	0.45	0.55	0.64	0.72	0.79	0.87	0.94	1.01	1.07
	100	0.32	0.51	0.63	0.73	0.82	0.89	0.97	1.04	1.11	1.18
	150	0.30	0.55	0.70	0.81	0.91	0.99	1.07	1.14	1.21	1.28
	200		0.57	0.76	0.89	0.99	1.08	1.16	1.23	1.30	1.37
	250			0.80	0.95	1.06	1.16	1.25	1.32	1.40	1.47
	300			0.83	1.00	1.13	1.24	1.33	1.41	1.49	1.56
13	0	0.24	0.32	0.40	0.47	0.54	0.61	0.68	0.74	0.80	0.86
	50	0.29	0.41	0.50	0.58	0.65	0.72	0.78	0.85	0.91	0.97
	100	0.30	0.47	0.58	0.67	0.75	0.82	0.89	0.95	1.01	1.07
	150	0.27	0.51	0.65	0.75	0.84	0.91	0.98	1.05	1.11	1.17
	200		0.53	0.71	0.83	0.92	1.00	1.07	1.14	1.21	1.27
	250			0.75	0.89	1.00	1.08	1.16	1.23	1.30	1.36
	300			0.78	0.95	1.06	1.16	1.24	1.32	1.39	1.45

Estimates of voluntary DM intake (kg/day) by lactating goats in a pen or stall environment

FCM (kg/day)	ADG (g/day)	30kg BW 7 MJ/kg DM	30kg BW 9 MJ/kg DM	30kg BW 11 MJ/kg DM	30kg BW 13 MJ/kg DM	40kg BW 7 MJ/kg DM	40kg BW 9 MJ/kg DM	40kg BW 11 MJ/kg DM	40kg BW 13 MJ/kg DM	50kg BW 7 MJ/kg DM	50kg BW 9 MJ/kg DM	50kg BW 11 MJ/kg DM	50kg BW 13 MJ/kg DM	60kg BW 7 MJ/kg DM	60kg BW 9 MJ/kg DM	60kg BW 11 MJ/kg DM	60kg BW 13 MJ/kg DM	70kg BW 7 MJ/kg DM	70kg BW 9 MJ/kg DM	70kg BW 11 MJ/kg DM	70kg BW 13 MJ/kg DM
Dairy goats[a]																					
1	–150			1						1.49	1.24	1.08	0.97	1.67	1.39	1.21	1.09	1.84	1.53	1.33	1.20
	–100					1.45	1.20	1.04	0.93	1.64	1.36	1.18	1.05	1.82	1.51	1.31	1.17	1.99	1.65	1.43	1.28
	–50	1.41	1.16	1.00	0.89	1.61	1.32	1.14	1.01	1.80	1.48	1.27	1.13	1.98	1.62	1.40	1.25	2.15	1.77	1.52	1.36
	0	1.56	1.27	1.09	0.96	1.76	1.44	1.23	1.09	1.95	1.59	1.37	1.21	2.13	1.74	1.50	1.33	2.30	1.88	1.62	1.44
	50		1.46	1.24	1.09		1.62	1.38	1.22	2.19	1.78	1.52	1.34	2.37	1.93	1.65	1.45	2.54	2.07	1.77	1.56
	150									2.43	1.96	1.67	1.46	2.60	2.11	1.79	1.58	2.78	2.25	1.92	1.69
2	–150									2.11	1.72	1.47	1.30	2.29	1.87	1.60	1.42	2.46	2.01	1.72	1.53
	–100						1.69	1.44	1.27	2.27	1.84	1.57	1.39	2.44	1.99	1.70	1.50	2.62	2.13	1.82	1.61
	–50		1.64	1.39	1.22		1.81	1.54	1.35	2.42	1.96	1.67	1.47	2.60	2.11	1.80	1.58	2.77	2.25	1.97	1.69
	0		1.76	1.49	1.30		1.93	1.63	1.43	2.58	2.08	1.77	1.55	2.76	2.23	1.90	1.66	2.93	2.37	2.02	1.77
	50		1.64	1.43				1.79	1.56	2.82	2.27	1.92	1.68	3.00	2.42	2.05	1.79	3.17	2.56	2.17	1.90
	100										2.46	2.07	1.81		2.60	2.20	1.92		2.75	2.32	2.03
3	–150										2.21	1.87	1.64		2.35	2.00	1.75		2.50	2.12	1.86
	–100						2.17	1.84	1.60		2.33	1.97	1.72		2.48	2.10	1.84		2.62	2.22	1.95
	–50						2.30	1.94	1.69		2.45	2.07	1.81		2.60	2.20	1.92		2.74	2.32	2.03
	0						2.42	2.03	1.77		2.57	2.17	1.89		2.72	2.30	2.00		2.86	2.42	2.11
	50							2.19	1.90		2.76	2.32	2.02		2.91	2.45	2.13		3.05	2.57	2.24
	100											2.48	2.15			2.60	2.26			2.73	2.37
4	–150										2.69	2.27	1.98		2.84	2.40	2.09		2.98	2.52	2.20
	–100										2.82	2.37	2.06		2.96	2.50	2.17		3.11	2.62	2.28
	–50										2.94	2.47	2.14		3.09	2.60	2.26		3.22	2.72	23.7
	0										3.06	2.57	2.23		3.21	2.70	2.34		3.35	2.82	2.45
	50										3.25	2.72	2.36		3.40	2.85	2.47		3.54	2.97	2.58
	100											2.88	2.49			3.00`	2.60			3.13	2.71
5	–150											2.67	2.31			2.80	2.43		3.47	2.92	2.51
	–100											2.77	2.40			2.90	2.51		3.59	3.02	2.62
	–50											2.87	2.48			3.00	2.60		3.72	3.12	2.71
	0											2.97	2.57			3.10	2.68		3.84	3.22	2.79
	50											3.12	2.70			3.25	2.81			3.37	2.92
	100											3.28	2.83			3.40	2.91			3.53	3.05
6	–150											3.07	2.65			3.20	2.76			3.32	2.81
	–100											3.17	2.74			3.30	2.85			3.42	2.96
	–50											3.27	2.82			3.40	2.93			3.52	3.04
	0											3.37	2.91			3.50	3.02			3.62	3.13
7	–150											3.60	3.10			3.72	3.21				
	–100											3.70	3.19			3.82	3.30				
	–50											3.80	3.27			3.92	3.38				
	0											3.90	3.36			4.02	3.47				

FCM = kgs of 4% Fat Corrected Milk, ADG = Average Daily Gain

Estimates of voluntary DM intake (kg/day) by mature goats in a pen or stall environment

FCM (kg/day)	ADG (g/day)	7 MJ/kg of ME				9 MJ/kg of ME				11 MJ/kg of ME				13 MJ/kg of ME			
		6% CP	9% CP	12% CP	15% CP	6% CP	9% CP	12% CP	15% CP	6% CP	9% CP	12% CP	15% CP	6% CP	9% CP	12% CP	15% CP
20	0	0.50	0.57	0.63	0.69	0.41	0.48	0.54	0.61	0.36	0.42	0.49	0.55	0.32	0.38	0.45	0.51
	20	0.52	0.58	0.65	0.71	0.43	0.50	0.56	0.63	0.38	0.44	0.51	0.57	0.34	0.40	0.47	0.53
	40					0.45	0.52	0.58	0.64	0.40	0.46	0.52	0.59	0.36	0.42	0.49	0.55
30	0	0.84	0.90	0.97	1.03	0.69	0.76	0.82	0.89	0.60	0.66	0.73	0.79	0.54	0.60	0.66	0.73
	20	0.91	0.98	1.04	1.11	0.77	0.83	0.90	0.96	0.67	0.74	0.80	0.87	0.61	0.67	0.74	0.80
	40	0.99	1.05	1.12	1.18	0.84	0.91	0.97	1.03	0.75	0.81	0.88	0.94	0.68	0.75	0.81	0.88
40	0	0.84	0.90	0.97	1.03	0.69	0.76	0.82	0.89	0.60	0.66	0.73	0.79	0.54	0.60	0.66	0.73
	20	0.91	0.98	1.04	1.11	0.77	0.83	0.90	0.96	0.67	0.74	0.80	0.87	0.61	0.67	0.70	0.80
	40	0.99	1.05	1.12	1.18	0.84	0.91	0.97	1.03	0.75	0.81	0.88	0.94	0.68	0.75	0.81	0.88
50	0	0.99	1.06	1.12	1.19	0.82	0.88	0.95	1.01	0.71	0.77	0.84	0.90	0.63	0.70	0.76	0.82
	20	1.07	1.14	1.20	1.27	0.90	0.96	1.03	1.09	0.79	0.85	0.92	0.98	0.71	0.78	0.84	0.90
	40	1.15	1.22	1.28	1.34	0.98	1.04	1.11	1.17	0.87	0.93	1.00	1.06	0.79	0.86	0.92	0.98
60	0	1.14	1.20	1.27	1.33	0.94	1.00	1.07	1.13	0.81	0.88	0.94	1.00	0.63	0.79	0.85	0.92
	20	1.22	1.28	1.35	1.41	1.02	1.08	1.15	1.21	0.89	0.96	1.02	1.09	0.71	0.87	0.93	1.00
	40	1.30	1.37	1.43	1.49	1.10	1.17	1.23	1.29	0.97	1.04	1.10	1.17	0.79	0.95	1.02	1.08
70	0	1.28	1.34	1.40	1.47	1.05	1.12	1.18	1.25	0.91	0.97	1.04	1.10	0.72	0.88	0.94	1.00
	20	1.36	1.42	1.49	1.55	1.14	1.20	1.26	1.33	0.99	1.06	1.12	1.19	0.81	0.96	1.02	1.09
	40	1.44	1.51	1.57	1.63	1.22	1.28	1.35		1.07	1.14	1.20	1.27	0.89	1.04	1.10	1.17
80	0	1.41	1.47	1.54	1.60	1.16	1.23	1.29	1.36	1.01	1.07	1.13	1.20	0.90	0.96	1.03	1.09
	20	1.49	1.56	1.62	1.69	1.25	1.31	1.37	1.44	1.09	1.15	1.22	1.28	0.98	1.04	1.11	1.17
	40	1.57	1.64	1.70	1.77	1.33	1.39	1.46	1.52	1.17	1.23	1.30	1.36	1.06	1.12	1.19	1.25

Estimates of voluntary DM intake (kg/day) by Angora goats in a pen or stall environment

FCM (kg/day)	ADG (g/day)	7 MJ/kg of ME				9 MJ/kg of ME				11 MJ/kg of ME				13 MJ/kg of ME			
		9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP
15kg BW																	
0	5	0.56	0.62	0.68	0.74	0.46	0.52	0.58	0.64	0.40	0.46	0.52	0.58	0.36	0.42	0.48	0.54
	10	0.58	0.64	0.70	0.76	0.48	0.54	0.60	0.66	0.42	0.48	0.54	0.60	0.37	0.43	0.49	0.55
	15	0.61	0.67	0.73	0.79	0.50	0.56	0.62	0.68	0.43	0.49	0.55	0.61	0.39	0.45	0.51	0.57
	20	0.64	0.70	0.76	0.82	0.52	0.58	0.64	0.70	0.45	0.51	0.57	0.63	0.40	0.46	0.52	0.58
	25	0.66	0.72	0.78	0.84	0.54	0.60	0.66	0.72	0.47	0.52	0.59	0.65	0.42	0.48	0.54	0.59
25	5	0.62	0.68	0.74	0.80	0.52	0.58	0.64	0.70	0.46	0.52	0.58	0.64	0.42	0.48	0.54	0.60
	10	0.65	0.71	0.77	0.83	0.55	0.61	0.66	0.72	0.48	0.54	0.60	0.66	0.44	0.49	0.55	0.61
	15	0.67	0.73	0.79	0.85	0.57	0.63	0.69	0.75	0.50	0.56	0.62	0.68	0.45	0.51	0.57	0.63
	20	0.70	0.76	0.82	0.88	0.59	0.65	0.71	0.77	0.51	0.57	0.63	0.69	0.46	0.52	0.58	0.64
	25	0.73	0.79	0.85	0.91	0.61	0.67	0.73	0.79	0.53	0.59	0.65	0.71	0.48	0.54	0.60	0.66
50	5	0.68	0.74	0.80	0.86	0.59	0.65	0.71	0.77	0.53	0.59	0.65	0.70	0.48	0.54	0.60	0.66
	10	0.71	0.77	0.83	0.90	0.61	0.67	0.73	0.79	0.54	0.60	0.66	0.72	0.50	0.56	0.62	0.68
	15	0.74	0.80	0.86	0.92	0.63	0.69	0.75	0.81	0.56	0.62	0.68	0.74	0.51	0.57	0.63	0.69
	20					0.65	0.71	0.77	0.83	0.58	0.64	0.70	0.76	0.53	0.59	0.65	0.71
	25					0.67	0.73	0.79	0.85	0.59	0.65	0.71	0.77	0.54	0.60	0.66	0.72
100	5					0.71	0.77	0.83	0.89	0.65	0.71	0.77	0.83	0.61	0.67	0.73	0.79
	10					0.73	0.79	0.85	0.91	0.67	0.73	0.79	0.85	0.62	0.68	0.74	0.80
	15					0.75	0.81	0.87	0.93	0.68	0.74	0.80	0.86	0.64	0.70	0.76	0.82
	20					0.77	0.83	0.89	0.95	0.70	0.76	0.82	0.88	0.65	0.71	0.77	0.83
	25									0.72	0.78	0.84	0.90	0.67	0.72	0.78	0.84
25kg BW																	
0	5	0.80	0.86	0.92	0.98	0.66	0.72	0.78	0.84	0.57	0.63	0.69	0.75	0.51	0.57	0.63	0.69
	10	0.82	0.88	0.94	1.00	0.68	0.74	0.80	0.86	0.59	0.65	0.71	0.77	0.53	0.58	0.64	0.70
	15	0.85	0.91	0.97	1.03	0.70	0.76	0.82	0.88	0.91	0.67	0.72	0.78	0.54	0.60	0.66	0.72
	20	0.88	0.94	1.00	1.06	0.72	0.78	0.84	0.90	0.62	0.68	0.74	0.80	0.55	0.61	0.67	0.73
	25	0.90	0.96	1.02	1.08	0.74	0.80	0.86	0.92	0.64	0.70	0.76	0.82	0.57	0.63	0.69	0.75
25	5	0.86	0.92	0.98	1.04	0.72	0.78	0.84	0.90	0.63	0.69	0.75	0.81	0.57	0.63	0.69	0.75
	10	0.89	0.95	1.01	0.07	0.74	0.80	0.86	0.92	0.65	0.71	0.77	0.83	0.59	0.65	0.71	0.77
	15	0.91	0.97	1.03	1.09	.076	0.82	0.88	0.94	0.67	0.73	0.79	0.85	0.60	0.63	0.72	0.78
	20	0.94	1.00	1.06	1.12	0.78	0.84	0.90	0.96	0.68	0.74	0.80	0.86	0.62	0.68	0.74	0.80
	25	0.97	1.03	1.09	1.15	0.80	0.86	0.92	0.98	0.70	0.76	0.82	0.88	0.63	0.69	0.75	0.81
50	5	0.92	0.98	1.04	1.10	0.78	0.84	0.90	0.96	0.70	0.76	0.82	0.88	0.64	0.700	0.75	0.81
	10	0.95	1.01	1.07	1.13	0.81	0.87	0.92	0.98	0.71	0.77	0.83	0.89	0.65	0.71	0.77	0.83
	15	0.98	1.04	1.10	1.16	0.83	0.89	0.95	1.01	0.73	0.79	0.85	0.91	0.66	0.72	0.78	0.84
	20					0.85	0.91	0.97	1.03	0.75	0.81	0.87	0.93	0.68	0.74	0.80	0.86
	25					0.87	0.93	0.99	1.05	0.76	0.82	0.88	0.94	0.69	0.75	0.81	0.87
100	5					0.91	0.97	1.03	1.09	0.82	0.88	0.94	1.00	0.76	0.82	0.88	0.94
	10					0.93	0.99	1.05	1.11	0.84	0.90	0.96	1.02	0.77	0.83	0.89	0.95
	15					0.95	1.01	1.07	1.13	0.86	0.91	0.97	1.03	0.79	0.85	0.91	0.97
	20					0.97	1.03	1.09	1.15	0.87	0.93	0.99	1.05	0.80	0.86	0.92	0.98
	25					0.99	1.05	1.11	1.17	0.89	0.95	1.01	1.07	0.82	0.88	0.94	1.00

FCM (kg/day)	ADG (g/day)	7 MJ/kg of ME				9 MJ/kg of ME				11 MJ/kg of ME				13 MJ/kg of ME			
		9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP	9% CP	12% CP	15% CP	18% CP
35kg BW																	
0	5	1.01	1.07	1.13	1.19	0.84	0.90	0.96	1.02	0.73	0.79	0.85	0.96	0.65	0.71	0.77	0.83
	10	1.04	1.10	1.16	1.22	0.85	0.92	0.98	1.04	0.74	0.80	0.86	0.92	0.66	0.72	0.78	0.84
	15	1.07	1.13	1.19	1.25	0.88	0.94	1.00	1.06	0.76	0.82	0.88	0.94	0.68	0.74	0.80	0.86
	20	1.09	1.15	1.21	1.27	0.90	0.96	1.02	1.08	0.78	0.84	0.90	0.96	0.69	0.75	0.81	0.87
	25	1.12	1.18	1.24	1.30	0.92	0.98	1.04	1.10	0.79	0.85	0.91	0.97	0.71	0.76	0.82	0.88
25	5	1.08	1.14	1.20	1.26	0.90	0.96	1.02	1.08	0.79	0.85	0.91	0.97	0.71	0.77	0.83	0.89
	10	1.10	1.16	1.22	1.28	0.92	0.98	1.04	1.10	0.80	0.86	0.92	0.98	0.72	0.78	0.84	0.90
	15	1.13	1.19	1.25	1.31	0.94	1.00	1.06	1.12	0.82	0.88	0.94	1.00	0.74	0.80	0.86	0.92
	20	1.16	1.22	1.28	1.34	0.96	1.02	1.08	1.14	0.84	0.90	0.96	1.02	0.75	0.81	0.87	0.93
	25	1.18	1.22	1.30	1.36	0.98	1.04	1.10	1.16	0.86	0.92	0.98	1.03	0.77	0.83	0.89	0.95
50	5	1.14	1.20	1.26	1.32	0.96	1.02	1.08	1.14	0.85	0.91	0.97	1.03	0.77	0.83	0.89	0.95
	10	1.17	1.23	1.29	1.35	0.98	1.04	1.10	1.16	0.87	0.93	0.99	1.05	0.79	0.85	0.91	0.97
	15	1.19	1.25	1.31	1.37	1.00	1.06	1.12	1.18	0.88	0.94	1.00	1.06	0.80	0.86	0.92	0.98
	20					1.02	1.08	1.14	1.20	0.90	0.96	1.02	1.08	0.82	0.88	0.93	0.99
	25					1.05	1.11	1.16	1.22	0.92	0.98	1.04	1.10	0.83	0.89	0.95	1.01
100	5					1.09	1.15	1.21	1.27	0.98	1.04	1.09	1.15	0.90	0.96	1.02	1.08
	10					1.11	1.17	1.23	1.29	0.99	1.05	1.11	1.17	0.91	0.97	1.03	1.09
	15					1.13	1.19	1.25	1.31	1.01	1.07	1.13	1.19	0.93	0.99	1.05	1.10
	20					1.15	1.21	1.27	1.33	1.03	1.09	1.15	1.21	0.94	1.00	1.06	1.12
	25					1.17	1.23	1.29	1.35	1.04	1.10	1.16	1.22	0.95	1.01	1.07	1.13
45kg BW																	
0	5	1.22	1.27	1.33	1.39	1.00	1.06	1.12	1.18	0.87	0.93	0.99	1.05	0.78	0.84	0.90	0.95
	10	1.24	1.30	1.36	1.42	1.02	1.08	1.14	1.20	0.89	0.95	1.01	1.06	0.79	0.85	0.91	0.97
	15	1.27	1.33	1.39	1.45	1.04	1.10	1.16	1.22	0.90	0.96	1.02	1.08	0.80	0.86	0.92	0.98
	20	1.29	1.35	1.41	1.47	1.07	1.13	1.18	1.24	0.92	0.98	1.04	1.10	0.82	0.88	0.94	1.00
	25	1.32	1.38	1.44	1.50	1.09	1.15	1.21	1.27	0.94	1.00	1.06	1.12	0.83	0.89	0.95	1.01
25	5	1.28	1.34	1.40	1.46	1.07	1.13	1.19	1.25	0.93	0.99	1.05	1.11	0.84	0.90	0.96	1.02
	10	1.30	1.36	1.42	1.48	1.09	1.15	1.21	1.27	0.95	1.01	1.07	1.13	0.85	0.91	0.97	1.03
	15	1.33	1.39	1.45	1.51	1.11	1.17	1.23	1.29	0.97	1.02	1.08	1.14	0.87	0.93	0.99	1.05
	20	1.36	1.42	1.48	1.54	1.13	1.19	1.25	1.31	0.98	1.04	1.10	1.16	0.88	0.94	1.00	1.06
	25	1.38	1.44	1.50	1.56	1.15	1.21	1.27	1.33	1.00	1.06	1.12	1.18	0.90	0.95	1.01	1.07
50	5	1.34	1.40	1.46	1.52	1.13	1.19	1.25	1.31	0.99	1.05	1.11	1.17	0.90	0.96	1.02	1.08
	10	1.37	1.42	1.49	1.55	1.15	1.21	1.27	1.33	1.01	1.07	1.13	1.19	0.91	0.97	1.03	1.09
	15	1.39	1.45	1.51	1.57	1.17	1.23	1.29	1.35	1.03	1.09	1.15	1.21	0.93	0.99	1.05	1.11
	20					1.19	1.25	1.31	1.37	1.04	1.10	1.16	1.22	0.94	1.00	1.06	1.12
	25					1.21	1.27	1.33	1.39	1.06	1.12	1.18	1.24	0.96	1.02	1.08	1.14
100	5					1.25	1.31	1.37	1.43	1.12	1.18	1.24	1.30	1.02	1.08	1.14	1.20
	10					1.27	1.33	1.39	1.45	1.14	1.20	1.25	1.31	1.04	1.10	1.16	1.22
	15					1.30	1.35	1.41	1.47	1.15	1.21	1.27	1.33	1.05	1.11	1.17	1.23
	20					1.32	1.38	1.44	1.49	1.17	1.23	1.29	1.35	1.07	1.13	1.19	1.25
	25					1.34	1.40	1.46	1.52	1.19	1.25	1.31	1.37	1.08	1.14	1.20	1.26

TG = Tissue Gain, FG = Fibre Gain/day.

Tool 7.3 – Edible shrubs and forbs

- Nutritive value of common goat feeds (average values)

Feed type	Energy MJ ME/kg DM	Crude protein % of DM
Pasture and fodder[1]		
Buffel grass	8.8	11.2
Curly windmill graass	8.9	12.5
Guinea grass[2]	9.8	16.2
Johnson grass	7.0	6.9
Kangaroo grass	7.5	5.4
Lucerne (early vegetative stage – 30cm)	10.0–11.0	22.0–28.0
Lucerne (late vegetative stage – 45cm)	9.0–10.0	18.0–24.0
Lucerne (early flowering – 50cm)	8.0–9.5	15.0–22.0
Lucerne hay	8.5	20.0
Mitchell grass	7.5	9.2
Pangola grass[2]	6.9	2.8
Paspalum	7.8	9.1
Purple pigeon grass	7.4	7.7
Queensland bluegrass	6.0–6.8	1.9–3.9
Rhodes grass	7.6	7.3
Temperate pasture mix: lush, green pasture	10.0–12.0	15.0–22.0
Temperate pasture mix: early summer pasture	7.0	10.0
Temperate pasture mix: late summer pasture (dry)	5.0–10.0	5.0
Temperature pasture mix: hay	1.0–9.0	5.0–10.0
Woollybutt	8.3	8.5
Trees and shrubs[3]		
Manuka leaves *(Leptospermum juniperinum)*	8.6	6.4
Gruie/Emu apple leaves *(Owenia acidula)*	8.9–10.1	10.0–14.0
Pine tree leaves *(Pinus radiata)*	7.2	9.0
Peppercorn tree leaves *(Schinus molle)*	10.2	20.3
Tamarisk leaves *(Tamarix parviflora)*	9.0	20.2

1 The nutritive value of pasture and fodder species changes throughout the year. For example, the feed value during the vegetative stage of plant growth will be distinctly different to the reproductive (flowering) stage. Environmental conditions can also affect the nutritive value of feed, e.g. frost. These factors need to be taken into account when assessing the value of pastures and crops as potential sources of goat feed. A feed analysis will be required to determine the exact feed quality.

2 Results of a single test only.

3 The nutritive value of fodder species changes throughout the year. For example, the feed value during the vegetative stage of plant growth will be distinctly different to the reproductive (flowering) stage. Environmental conditons can also affect the nutritive value of feed eg frost. These factors need to be taken into account when assessing the value of fodder species as potential sources of goat feed. A feed analysis will be required to determine the exact feed quality.

The data in these tables has been sourced from:

- McGregor, B. (2003). *Nutrition of goats during drought.* RIRDC.
- NSW Department of Primary Industries. (2005).
- Kaiser AG, Piltz JW, Burns HM and Griffiths, NW (2003), *Successful Silage* TopFodder manual, Dairy Australia and NSW Department of Primary Industries.

Tool 7.4 – Nutritional disorders

The information below will assist in identifying and managing the following nutritional disorders that can occur in goats:

- bloat
- grain poisoning
- copper deficiency
- selenium deficiency
- cobalt deficiency
- iodine deficiency
- thiamine (Vitamin B1) deficiency.

This summary provides details of the prevailing conditions under which each problem is likely to occur, explains how to diagnose the problem and lists preventative management strategies.

◆ Bloat

Conditions when likely to occur:

- Consumption of large amounts of lush, green, leguminous feed or lucerne hay.

Diagnosis:

- Clinical signs: gases form in the rumen causing distension on the left upper side. Death can occur quickly as pressure builds on the diaphragm causing failure of heart and lungs.
- Pasture assessment: at-risk pastures are those with a high proportion of legume, lush and in vegetative growth.

Treatment:

- Cooking oil or a bloat oil product can be administered to break up the gaseous foam in the rumen. In acute situations, a trocar can be used to relieve the pressure. It must be inserted in the left paralumbar fossa and left intact until the crisis is over. Premature removal of the trocar prevents the hole in the rumen corresponding to the hole in the skin.

Preventative management strategies:

- Avoid grazing high-risk pasture.
- Provide access to roughage in the form of hay or dry pasture.
- For producers adopting intensive rotational grazing, slow the rotation so goats are grazing more mature pasture. This may reduce risk but will not eliminate it.
- In intensive grazing or strip grazing situations, daily spraying of bloat oil on high-risk pastures prior to grazing may be an option. This strategy will not be cost-effective or practical in many situations. Bloat oil in water troughs may be considered if water availability is controlled. Bloat blocks are less reliable.
- During periods of lush pasture growth maintain regular routine and intake of food and water.

◆ Grain poisoning

Conditions when likely to occur:

- Rapid introduction to grain in the diet.
- Ingestion of large quantities of grain in a short period of time, resulting in an excessive build-up of lactic acid in the rumen.
- Changing from one type of grain to another too quickly.
- Rapid increase in the level of grain feeding.

Diagnosis:

- Kicking at the belly, obvious pain and discomfort, grinding of teeth, standing dejectedly, not moving, sometimes bloated and scouring.

Preventative management strategies:

- Change the diet slowly; any change in feed type or amount of ration should be gradual. Ensure adequate fibre in the diet.
- Use a buffer in the ration, e.g. bicarbonate or bentonite
- Avoid over-processing grain – preferably feed whole grain.

◆ Copper deficiency

Conditions when likely to occur:

- Copper deficient regions such as coastal sandy soils, granite soils and peat swamps; exacerbated by excess molybdenum or lime application.
- Deficiency typically occurs after an extended period of green feed. Copper is more available in dry feed.
- Growing stock and breeding stock are more susceptible to copper deficiency than other stock classes.

Diagnosis:

- Biopsy: liver copper levels are very low, e.g. 2.6–17.2mg/kg (normal levels are greater than 40mg/kg).
- Blood samples should be taken from healthy goats and compared with those from affected goats. Normal serum or plasma copper levels are 500–1,100mcg/litre.
- Soil: copper levels in the soil are poorly correlated with animal status, so do not use soil test to assess animal copper status. A soil copper level of 5ppm is adequate, but 4ppm molybdenum reduces available copper by 50%. Sulphur levels of 2g/kg or above also reduce copper availability.
- Abattoir: collection of liver samples if field biopsy not possible.
- Clinical signs: rough dull coat, poor growth, scouring, anaemia and poor reproductive ability.

- Kids may have an erratic swaying gait (swayback), usually weak and in poor condition. This is followed by paralysis. Confirmation of copper deficiency should be through blood sampling a proportion of the herd. Having done this, the most appropriate level of copper supplement can be determined.

Preventative management strategies:

- Treat stock with a copper injection prior to the high-risk periods of winter and spring. Alternatively, copper capsules can be used to provide longer-term (12 months) prevention.
- If copper levels in the herbage are low, top-dress pasture periodically with copper (usually every 5–7 years).
- When applying molybdenum to a pasture, also add copper, if copper levels are marginal in the herbage.
- Discuss dosage and management options with your veterinarian and agronomist. Be aware that toxicity can be induced by overdosing with copper supplements.

◆ Selenium deficiency

Conditions when likely to occur:

- Selenium-deficient regions, such as coastal sandy soils, New South Wales tablelands, acidic soils, sedimentary and granite soils, usually in high-rainfall regions, exacerbated by high superphosphate application and clover dominance. Refer to *Module 6 Husbandry* for more detail on selenium deficient regions.
- Typically, deficiencies are greatest when feed is lush
- Young growing stock are most at risk.

Diagnosis:

- Blood biochemistry: levels of the selenium-containing enzyme, glutathione peroxidase in uncoagulated whole blood of <40 IU are diagnostic for selenium-deficiency. Pasture levels of <0.2mg Se/kg DM also indicate a deficiency but soil levels are usually an insensitive indicator.
- New Zealand work suggests goats have a higher requirement for Vitamin E than sheep and this may also be true for selenium.
- Clinical signs: stiff-legged gait, arched back and death.

Preventative management strategies:

- Both selenium and Vitamin E are necessary.
- Selenium can be administered as oral doses, injection or slow-release pellets lodged in the rumen.
- Selenium is potentially an extremely toxic substance and must be administered with care. Note that additional selenium is commonly found in clostridial vaccines and anthelmintic drenches, so take care not to oversupply.
- Selenium should be administered to does prior to joining and again one month before kidding.

- Treat kids at marking. Repeat dose for kids at weaning, with further doses at three, six, nine and 12 weeks up to joining.
- Slow selenium pellets or long-acting injections can be used for longer-term protection.
- Top-dress pasture – the decision to top-dress should be made on the basis of cost/benefit analysis. It is usually too expensive to treat pastures, except in high stocking rate situations.
- Vitamin E is administered by injection. It can also be mixed with a grain ration and fed immediately.
- Discuss dosage and management options with your veterinarian and agronomist.

◆ Cobalt deficiency

Conditions when likely to occur:

- Cobalt-deficient regions such as coastal calcareous sands, high-rainfall granite soils and krasnozem soils, exacerbated by liming and high superphosphate application, especially in lush seasons. Refer to *Module 6 Husbandry* for more information.
- It has not been diagnosed in goats.

Diagnosis:

- Blood biochemistry: Vitamin B12-deficient plasma, with levels less than 0.2mcg/ml indicate deficiency. A normal liver contains 0.32–2.0mcg/g of cobalt.
- Pasture cobalt levels can be assessed, but are rarely tested. Levels below 0.8 parts per million indicate deficiency.
- Clinical signs: ill-thrift, weepy eyes, severe wasting and eventually death.
- Clinical response to deficiency treatment can be tested by comparing a treated mob with a control (untreated) mob. Treatment group would receive either a Vitamin B12 injection or cobalt pellets.

Preventative management strategies:

- Vitamin B12 injection will provide prevention for about 8–12 weeks. Slow-release cobalt pellets can be used for longer-term prevention.
- Top-dressing pastures with cobalt gives variable responses. Cobalt levels in pasture can be tested – below 0.8 parts per million indicates a deficiency.
- Discuss dosage and management options with your veterinarian and agronomist.

◆ Iodine deficiency

Conditions when likely to occur:

- Iodine deficiency occurs especially in mountainous areas such as on the Great Dividing Range in Victoria and coastal New South Wales.
- Iodine levels tend to be low in lush clover-dominant pastures with a history of high superphosphate application.

Diagnosis:

- Clinical signs: thyroid gland swells producing a goitre; this is only a problem in newborn kids. Adults appear to tolerate seasonal deficits.

Preventative management strategies:

- Drenching is recommended. Avoid feeding iodine as a lick as it is important to accurately control intake by the doe.
- Pregnant does grazing in high-rainfall areas should receive a drench of iodine once or, in some cases, twice during the last two months of their pregnancy.
- Feed seaweed.

◆ Thiamine (Vitamin B1) deficiency

Conditions when likely to occur:

- Goats eating plants that are rich in the enzyme 'thiaminase', such as bracken fern, mulga fern, rock fern and nardoo.
- After a dry period, the plants listed above will get away more quickly than other pasture species. Stock eating the fresh growth of these plants are at risk.
- Feeding large quantity of molasses, or a sudden increase in concentrates.
- Sudden changes of diet may predispose to thiamine deficiency, especially in young stock.

Diagnosis:

- Clinical signs include stargazing – head up and tilted back, disorientation and aimless wandering, apparent blindness, oscillating eyes, may appear cross-eyed, lying down, head thrown back and stiff legs, convulsions and coma.

Preventative management strategies:

- Graze goats on fern-free paddocks until there is sufficient pasture or other grazing opportunities.
- Make available alternative feed, i.e. good-quality hay so stock are less likely to eat fern.
- Reduce the amount of fern on the property.

The information presented in this tool has been sourced from a number of references:

- Simmonds J (ed.) (2001) *Australian Goat Notes*. Australian Cashmere Growers Association.
- Hungerford TG (1990) *Diseases of Livestock*. Ninth edition. McGraw-Hill.
- Vincent B (2005) *Meat Goats Breeding, Production and Marketing*. Landlinks Press.

Tool 7.5 – Toxic plants

It is important that you are able to recognise plants in your area that are toxic, particularly those which are toxic to goats. In terms of managing the threat posed by toxic plants there are a number of factors that you need to consider:

- Poisonous plants may include pasture species at certain growth stages and, under certain environmental conditions, native species and garden plants.
- When animals are hungry they may gorge themselves on things they would otherwise avoid. Therefore, do not introduce hungry goats to areas where toxic plants are known to be growing. If in doubt, let a few tasters in for a short period of time to that the area is safe.
- Goats will readily try something new. Be aware that goats may start eating poisonous plants when moved to a new area.
- Goats grazing in a particular area for extended periods may become accustomed to eating small amounts of toxic plant material, but new mobs introduced to the area will not have the same tolerance and can be adversely affected by eating the same plants.
- Herbicide treatments tend to increase the palatability of plants, including toxic plants.
- The relative toxicity of plants may vary according to the season and the stage of plant growth. Regrowth and young suckers can be especially dangerous.
- Wilting in dry conditions and rapid growth after rain can increase the toxicity of a plant. Nitrite poisoning can be a problem when grazing green oat crops and other specific plants, such as variegated thistle, nitrogen-fertilised ryegrass, capeweed and mintweed.
- Some plants may only be toxic when growing in a particular soil type.
- Some plant toxins can be cumulative: the damage to internal organs may not be noticed immediately, but may develop over time.
- Applying fertiliser to promote lush growth may increase toxicity, e.g. applications of urea can increase the risk of nitrate poisoning.
- Stressful growth conditions, such as drought and insect attack, may cause toxins to concentrate in the plant.
- Small amounts of toxic plants fed in a well-mixed feed or as part of a pasture diet may be tolerated.
- Animals suffering from mineral deficiencies may develop cravings which cause them to eat plants that they would normally reject.
- Plant parts can vary in their relative toxicity. In some plants it may only be the seeds or the bark that is toxic.

There are many good references that can help you to understand which plants are toxic, the level of toxicity, the impact of consumption by stock and the environmental factors that promote toxicity. Some useful titles include:

- Everist SL (1981), *Poisonous Plants of Australia*. Revised edition. Angus and Robertson, Sydney and London.
- McBarron EJ (1983), *Poisonous Plants: A handbook for farmers and graziers,* Inkata press.
- McBarron EJ (1976), *Medical and veterinary aspects of plant poisoning in New South Wales,* New South Wales Agriculture, Simmonds.
- Holst H, Bourke P (2000), *The palatability and potential toxicity of Australian weeds to goats,* RIRDC.
- Colby P (2000), *Natural Goat and Alpaca Care,* Landlinks Press.
- Vincent B (2005), *Meat Goats Breeding*, *Production and Marketing*, Landlinks Press.

Tool 7.6 – Safe upper limits for substances possibly contained in water for livestock

The US National Academy of Sciences (1972 and 1974) has prepared guidelines on the safety level of many toxic inorganic elements in livestock drinking water and this is presented in the table below. These guidelines have a wide safety margin. They are based on amounts normally found in usable surface and groundwater and are not necessarily the limits of animal tolerance. This approach is taken since the safe concentration of these substances is dependent upon many factors including the quantity of water an animal consumes each day and the weight of the animal. Consult the original discussions presented by the National Academy of Sciences publication before using water of questionable quality.

◆ Safe upper limits for substances possibly contained in water for livestock

Substance	Safe upper limit of concentration
Aluminium (Al)	5ppm
Arsenic (As)	0.2ppm
Boron (B)	5ppm
Cadmium (Cd)	0.05ppm
Chromium (Cr)	1ppm
Cobalt (Co)	1ppm
Copper (Cu)	0.5ppm
Fluoride (F)	2ppm
Lead (Pb)	0.05ppm
Mercury (Hg)	0.01ppm
Nitrate + Nitrite	100ppm
Nitrite	10ppm
Selenium (Se)	0.05 to 0.10ppm
Vanadium (V)	0.1ppm
Zinc (Zn)	24ppm
Total dissolved solids	10,000ppm
Magnesium + sodium sulfates	5,000ppm
Alkalinity (carbonate + bicarbonate)	2,000ppm

Source: US National Academy of Sciences, 1972 and 1974

Tool 7.7 – Palatability of plants commonly eaten by goats

- Trees and shrubs

Scientific name	Common name	Highly palatable	Palatable	Moderately palatable	Eaten occasionally
Acacia aneura	mulga	mature	–	young	–
Acacia escelsa	ironwood	–	–	–	all stages
Acacia homalophylla	yarran	–	–	all stages	–
Acacia meamsli	black wattle	–	flowering	–	–
Acacia pardoxa	kangaroo thorn	–	–	–	all stages
Acacia spp. (other)	various names	–	–	all stages	–
Apophyllum anomalum	warrior bush (broombush, currant bush)	all stages	–	–	–
Atalaya hemiglauca	whitewood	all stages	–	–	–
Atriplex spp.	saltbush	–	–	all stages	–
Brachychiton populneum	kurrajong	all stages	–	–	–
Callitris columellaris	white cyprus pine	–	–	–	all stages
Callitris endlicheri	black cyprus pine	–	–	all stages	–
Capparis mitchellii	white orange (orange bush)	–	all stages	–	–
Cassia artemisioides	silver cassia	–	–	–	all stages
Cassia eremophila	punty bush (desert cassia)	–	–	–	–
Cassinia spp.	dolly bush, chinese shrub (*c.aculatua*), sifton bush (*c.aculatua*), biddy bush, sticky cassinia	–	–	–	isolated plants
Casuarina cristata	belah	all stages	–	–	–
Chamaecytisus proliferus	lucerne tree (tagasaste)	all stages	–	–	–
Chenopodium nitrariaceum	nitre goosefoot (nitre bush)	all stages	–	–	–
Crataegus spp.	hawthorn	–	–	all stages	–
Cytisus scoparius	scotch broom	all stages	–	–	–
Dodonaea attenuata	narrowleaf hop bush	all stages	–	–	–
Dodonaea viscosa	hop bush	–	flowering	–	–

Scientific name	Common name	Highly palatable	Palatable	Moderately palatable	Eaten occasionally
Eremophila longifolia	emu-bush	all stages	–	–	–
Eremophila mitchellii	budda	–	–	–	all stages
Eucalyptus albens	white box	–	flowering	–	–
Eucalyptus melliodora	yellow box	–	–	sucker regrowth	–
Eucalyptus polyanthemos	red box	–	flowering	–	–
Eucalyptus populnea	bimble box (poplar box)	–	–	–	all stages
Eucalyptus spp.	box, gum and mallee	sucker leaves	–	all stages	–
Geijera parviflora	wilga	–	–	–	all stages
Gomphocarpus fruticose	narrowleaf cotton bush	–	–	–	isolated mature plants
Heterodendrum oleifolium	rosewood	all stages	–	–	–

◆ Grasses and rushes

Scientific name	Common name	Highly palatable	Palatable	Moderately palatable	Eaten occasionally
Aristida spp.	wire grass	–	–	all stages	–
Chloris spp.	windmill grass	–	flowering	–	–
Cyperus spp.	nutgrasses	all stages	–	–	–
Danthonia spp.	wallaby grass	–	flowering	–	–
Eragrostis australasica	canegrass	–	–	all stages	–
Hordeum leporinum	barley grass	–	–	all stages	–
Juncus spp.	rushes	–	–	flowering	–
Lolium spp.	ryegrass	all stages	–	–	–
Nassella trichotoma	serrated tussock	–	–	–	all stages
Poa labillardieri	poa tussock	–	–	all stages	–
Sporobolus caroli	yakka grass (fairy grass)	–	flowering	–	–
Stipa spp.	speargrass	–	–	all stages	–

◆ Herbs

Scientific name	Common name	Highly palatable	Palatable	Moderately palatable	Eaten occasionally
Rumex crispus	curled dock	–	flowering	–	–
Sclerolaena birchii	galvanised burr	–	–	–	all stages
Silybum marianum	vaiegated thistle	–	all stages	–	–
Sisymbrium spp.	mustard weed	–	flowering	–	–
Solanum carolinense	Carolina horse nettle	–	all stages	–	–
Trifolium spp.	clovers	–	–	–	mature
Urtica incisa	scrub nettle, tall nettle	–	all stages	–	–
Ventilago viminalis	supplejack	all stages	–	–	–
Verbena bonariensis	purpletop	–	flowering	–	–

Tool 7.8 – Lot feeding goats

The information presented in this tool has been generously provided by the University of Queensland. We would like to thank to the authors, Mark Flint and Peter Murray, for their cooperation. The document was originally produced by the University of Queensland and published by the Queensland Department of Primary Industries.

◆ Introduction

This guide discusses what you need to know to operate a commercial goat feedlot. For information relating to animal welfare in commercial goat feedlots, contact your state or territory department of primary industry and agriculture.

◆ What is lot feeding?

Lot feeding is the confining of grazing animals for intensive management, primarily for optimal growth necessary for the economic preparation of animals for slaughter.

◆ What problems may occur?

The key problems associated with managing goats in a feedlot include:

- the high occurrence of malnourishment and exhaustion, aggression and disease induced by stress
- the difficulty of containing agile animals, particularly individual goats that have little respect for normal stock fences or have had little or minimal handling prior to pre-feedlot habituation
- specific handling techniques required to move and care for goats
- the unique nutritional requirements of these animals.

Critical to planning a lot feeding facility is defining specific outcomes. these include determining access of lot fed goats to markets, the potential profitability of lot feeding under the given conditions, and contingency plans in case lot feeding is determined to be unprofitable.

If lot feeding is not likely to be profitable or advantageous, then it may be better to:

- sell goats without lot feeding them
- maintain these animals on poor quality pastures until quality fodder crops and/ or pastures become available
- agist goats.

◆ Costs of lot feeding goats

The purchase of stock and the cost of feeding will be the major economic outlays once the feedlot itself is established. Feed can cost over $400 per tonne, and even between September and March when goats grow best, it will take between 7kg and 14kg of feed to produce 1kg of liveweight. Naturally, such estimates vary seasonally and with locality.

Costs of vaccinations and drenching, running the feedlot (including the employment of staff, transport of goats to the abattoir), slaughter and processing costs, and risk assessments (mortality and market guarantees) should be considered before proceeding.

◆ Selecting goats for the feedlot

Suitable animals must be selected. Loss of stock due to poor pre-feedlot selection may result in significant economic losses. Here are some essential factors:

- **Identification –** by law, goats cannot be sold or held without appropriate identification. This may take the form of an NLIS tag. Earmarking, tattooing or a plastic ear tag are also used in conjunction with the NLIS tag.
- **Body condition –** goats in a feedlot must be in good physical condition. Feedlots are used to finish goats for slaughter, not to revive goats in poor condition. Reviving goats is unprofitable and poses a risk that disease may spread if the animals are in poor condition on entry to the feedlot.
- **Temperament –** do not choose 'wild' or skittish goats for a feedlot. Even with pre-feedlot habituation, a goat that does not respect fences or will not tolerate interaction with humans will not perform well in a feedlot.
- **Conformation –** choose goats with good conformation. This includes a natural shaped back (not too flat and not too curved) and good feet. In a feedlot, animals undergo a rapid increase in liveweight which places more pressure on their limbs and therefore the goat must not show signs of lameness from weight bearing. If a goat is limping, check between the hooves for abscesses, foot rot or soft-tissue damage. If the hoof is healthy, then check the leg for muscle, tendon or skeletal damage.
- **Age –** lot feeding is designed to maximise the growth of young goats during their rapid growth phase of development (around six months of age, or the first summer after birth). Lot feeding is of little benefit to older goats and although they will respond well to high quality feed and intensive management, their liveweight gains are less. Two good indicators of age are horn size (the larger the horns, the older the goat) and the number of adult teeth. This is similar to sheep, where each additional adult tooth approximately equals an extra six months of age up to maturity.
- **Mouth** — check the mouths of goats for overshot or undershot jaws, and look for 'broken-down' teeth because these may impede feed intake.
- **Entry liveweight** – markets determine the entry liveweight (carcase weight) of goats being finished in the feedlot. Market requirements should be known before the start of lot feeding.
- **Castration status** – in a feedlot, entire males are likely to have higher liveweight gains than castrated males.

◆ Pre-feedlot habituation

Lot feeding of goats includes both a pre-feedlot habituation phase and a feedlot phase. Pre-feedlot habituation is a necessary process if animals are to be accustomed to feedlot facilities prior to lot feeding. It is particularly important when using goats of feral origin or goats from large extensive husbandry systems due to their 'flighty' nature when introduced to intensive management systems.

Pre-feedlot habituation reduces stress and encourages animals to eat the maximum amount of feed from their first day in the feedlot. Stressors may include a new ration, high stocking densities compared to extensive grazing, and new facilities and management practices.

1. **Pre-feedlot drenching and vaccinating**
   Prior to entry to the habituation yards, each animal should be drenched and vaccinated to control internal parasites and reduce the risk of disease transmission between animals. Do this as the goats are being weighed into the pre-feedlot facility. These handling procedures should accustom goats to the human interactions they will experience in the feedlot.

2. **Stocking density and duration in pre-feedlot habituation**
   Goats should be held at about 64 goats per hectare for a period of five days.

3. **Pre-feedlot weighing and identification of shy feeders**
   Records of each goat's performance should be documented. Weigh the goats at the start of pre-feedlot habituation and periodically to identify the change in liveweight for each goat during the habituation period. If a goat loses weight during this pre-feedlot habituation period, it may indicate the animal's future performance in the feedlot, poor health status and/or poor adaptation to the ration. If a goat loses excessive weight during the pre-feedlot habituation period (for example, greater than 200g/day) then it should not be entered into the feedlot.

4. **Pre-feedlot water and feed ration**
   Goats need access to a minimum of 4L of cool, clean water per head per day. This requirement may be greater than 4L of water per day during summer and lower during winter. During the pre-feedlot habituation goats are to be grazed on pastures similar to those they have been recently grazing and fed chaff or hay on the first day to provide a safe gut fill (about 2% of liveweight per head), then fed their feedlot ration.

5. **General hygiene provisions**
   Feed troughs should be covered to prevent goats from standing in and contaminating the feed. Contaminated or uneaten feed should be removed daily to allow continuous access to fresh feed. Hay, if fed, should be provided in elevated hay racks. Spilled residues must be removed daily to avoid contamination. Constructing a cement pad under the troughs and racks will allow for easier cleaning of spilled feed. Water troughs should be cleaned every second day. Constructing a cement pad under the troughs will minimise mud (and contamination) from overflowing water.

6. **Feedlot drenching and vaccinating**
   Goats should be treated with:

   - a drench registered for use on goats to control internal parasites including lung and intestinal worms
   - a 6-in-1® vaccine at the start of the pre-feedlot habituation period to control the following bacterial diseases:
     - caseous lymphadenitis (caused by *Corynebacterium pseudotuberculosis*), enterotoxemia (caused by *Clostridium perfringens* type D)

    - tetanus (caused by *Clostridium tetani*)
    - black disease (a non-enteric, clostridial infection caused by sporulated organisms within Kupffer's cells in the animal's blood and liver – usually associated with liver fluke)
    - malignant oedema (caused by *Clostridium septicum*)
    - blackleg (caused by *Clostridium chauvoei*)
- selected chemicals for control of external parasites such as lice and ticks if necessary.

Treatments may incur withholding periods so carefully read labels before use. Withholding periods vary significantly between treatments and should be known before application. Follow safety precautions. Always read the label.

7. **Feedlot weighing**

Each goat should be weighed on entry into the feedlot and again periodically with the minimum of disturbance. Weekly weighing may cause distress which is evidenced by a decrease in daily Dry Matter Intakes, and it may be necessary to weigh less frequently.

Weighing should occur at the same time after the same practices have occurred; that is, if goats are fed before weighing on one week, then they should be fed before weighing every week for the duration of the lot-feeding period. This is to ensure that gut fill is approximately the same at each weighing, and no change in regime occurs that may induce stress among the goats.

Records of liveweight change should be kept for each goat.

8. **Monitoring the health of the goats in the feedlot**

Signs of illness and stress-induced starvation in the goats should be checked daily. If any goat is sick or not eating, it should be removed from the pen and placed in an isolation pen where it is not stressed by competition from many goats and is not able to infect the rest of the feedlot flock. Sick goats or shy feeders may be subject to aggressive dominance by other goats. This can be disastrous in a feedlot situation. If in doubt as to the health status of a goat, consult a veterinarian.

9. **Feedlot pen stocking density and pen size**

In a feedlot, goats can be stocked at the equivalent of 1,667 goats per hectare as long as a pre-feedlot habituation stage has been undertaken. This stocking density is the equivalent of 5.9m^2 per head and is approximately the same as the recommended density for lambs in a feedlot. Pens should be rectangular and approximately 42m by 60m to create manageable groups and to mimic 'natural' flock sizes of around 400 goats per pen.

10. **Lot feeding duration**

Goats should not be lot fed for a period exceeding 35 to 42 days, as goats easily get bored and stressed in feedlots and because their feed conversion ratios are often not good. The longer they remain on feed, the less economical the lot feeding exercise becomes. Novel environmental stimulation (toys) helps to reduce boredom and stress.

Toys may take the form of a pile of stacked railway sleepers and old car tyres or mounds of soil to climb on, or suspended plastic milk bottles and pipes to mouth and butt. After 35 to 42 days the relative increase in feed costs are likely to exceed any additional liveweight gains and may make the process unprofitable.

This period may be longer if cheaper feed can be obtained and/or goats are introduced to the feedlot at a lower starting liveweight, but be aware that additional novel environmental stimulation will be required for such animals to combat boredom and stress. Liveweight gains may not be as great after 35 to 42 days.

11. **Water and feed ration/formulation**

- Lot-fed goats may require up to 4L water/day. Goats will accept a level of up to 1.5% (5000mg NaCl/L) salt in their drinking water if the amount of salt is slowly increased up to this maximum salt concentration. This will allow the use of water from bores in feedlots. However, clean cool water (with a salt content of less than 2,000mg NaCl/L) is preferred as it aids digestion and reduces the risk of introducing water-borne diseases.
- Feed combinations to maximise growth: Because rapid growth is required, it is usually an advantage to feed a mixture of hay and grain ad libitum. A cereal grain and legume hay is suggested at a ratio of 70:30 cereal grain to hay. Take precautions when starting to grainfeed to minimise the risks of lactic acidosis, liver damage and urinary calculi. A mash containing a mixture of chaff and grains may provide a complete diet, available in a constant ratio without allowing animals to select components of the diet. This may also ensure the goats eat the desired energy and protein levels required for rapid growth.

A young, rapidly growing goat can eat over 1.3kg of high-quality ration per day and grow at over 200g per day. It is vital that animals are provided with more than this amount of ration if growth is not to be limited. Rations should consist of 90% dry matter (DM), 30 to 35% neutral digestible fibre with a crude protein content between 15% and 17% and a metabolisable energy (ME) content of 9-12 megajoules ME/kg ration (DM).

Additives to the ration such as minerals, salt, sodium bentonite, vitamins, urea and a coccidiostat may be required. Before lot feeding goats, consult an experienced small ruminant nutritionist. In the confines of a feedlot, goats should not have access to toxic shrubs, trees or plants that may poison them.

◆ Pre-feedlot habituation yard construction and facilities

Prior to lot feeding, goats should be habituated to the facilities they will encounter on introduction to the feedlot.

1. **Fences**

Goats should be held in a habituation education yard with seven or nine-strand, plain-wire electric fences during the pre-feedlot habituation process to teach them to respect and keep away from the fences. The fence should be constructed with alternating live and earth wires (top wire earth), with the gaps between each wire decreasing down the fence (wires one to two, at the top, have a gap of 20cm, whereas wires eight to nine, at the bottom, have a gap of 5cm). The bottom wire (which is an earth) touches the ground. The fence should be electrified to 9,000V. The goats should be stocked at 64 goats per hectare.

2. **Feed and water troughs**
   Facilities used during this period (water and feed troughs) should be the same as (or at least very similar to) those to be encountered in the feedlot to help familiarise animals with the eating and drinking facilities in the feedlot. Both feed and water troughs should be designed to be easily cleaned. Water troughs should supply a minimum of 4L of water per goat per day and the water must be kept cool. Delivery pipes need to be buried under the ground and avoid large shallow troughs. Feed troughs should be designed to provide 5cm of trough space per goat with ad libitum feed.
3. **Pre-feedlot habituation pen shelter**
   Goats need access to shelter from adverse weather conditions. Shelter from the wind, rain, direct sun and cold should be sufficient to cover all goats in the yard at the same time.

◆ Feedlot pen construction and facilities

A goat feedlot requires several basic facilities including individual rectangular yards (42 x 60m) each with feed troughs, water troughs, suitable environmental enrichment and a central shelter (running north–south to allow continuous drying of the shaded area by the east–west track of the sun), access to laneways leading to handling yards and loading ramps. A feedlot should include at least one, and preferably several, isolation pens with separate water and feed sources, loading ramp and drainage system to avoid any contamination of healthy goats in other pens by sick goats (Diagram A). In many cases, lamb feedlots will be modified to accommodate goats, and this may result in significant savings in establishment costs.

The slope in the feedlot pen is critical. Ideally it should be between 3° to 4° to ensure rainwater can quickly drain away, but not too steep that erosion occurs. Boggy/muddy feedlot pads lead to feet disorders in the goats. The water that flows from the pens should be captured in drains and sedimented in tailings dams to avoid contamination of local streams. The nutrient-rich water can be used for irrigation/fertilsation of pastures and the sediment can also be used as fertiliser.

1. **Fences**
   Feedlots should be fenced with at least 1,100mm high (100 x 50mm mesh) weld mesh topped with fabricated wire netting to create a 1,500mm high goat-proof fence. Weld mesh fences need to be checked daily to ensure no goats have their head caught. No gaps should be left under the weld mesh or other escape routes left available to the goats. Any gap large enough for a goat to put its head through, is large enough to become a potential escape route, or goats may get their heads caught. Angled strainer posts can be climbed by goats, so posts should be external to the weld mesh. Plain-wire electric fences of nine strands are usable in a feedlot, but are not advised. Do not electrify weld mesh. If goats get their heads caught in an electrified weld mesh fence, it is likely to be fatal.

2. **Feed and water troughs**
   Feed troughs should be fixed 400mm above the ground with a cover to prevent goats from standing in and contaminating the feed. A minimum feed trough length of 5cm per head is recommended. Hay racks should be elevated to goat head height. The base of the rack should be approximately 800mm above the ground. Feed troughs do not have to be complicated or expensive. They may be open-style feeders with a cover to prevent goats from jumping into the trough. Water troughs should supply clean cool water at a minimum rate of 4L of water per goat per day.

3. **Shelter in a feedlot**
   Goats do not like rain, extreme heat or extreme cold. The feedlot should provide shelter for goats that protects them from these types of adverse weather conditions. Shelter should be an open awning design that allows for unimpeded ventilation while still providing sufficient space so that each goat may have shelter during adverse weather without overcrowding occurring. Shelter should provide one square metre of space per goat. The awning of the shelter should extend to provide goats with maximum coverage from the midday sun and also so that the pad can dry out.

   For sheltering from cold, the awning should provide a wind break by having walls that prevent the unimpeded flow of air while still facilitating ventilation – for example, wooden barriers (short walls) and corrugated iron sheeting, such as the types used in cattle feedlots. For sheltering from heat, enough space per goat should be provided so that body heat radiation from surrounding goats does not adversely affect the individual. For protection from wet conditions, adequate floor drainage should be made available and the feedlot should be constructed with a ground slope of 3° to aid drainage.

4. **Feedlot pen enrichment**
   All pens should be enriched with 'toys' to help alleviate boredom and disruptive behaviours in the goats. Toys do not have to be expensive or complex. Toys may take the form of a pile of stacked railway sleepers and old car tyres or mounds of soil to climb on, or suspended plastic milk bottles and pipes to mouth and butt. The addition of a new toy each week should continue to stimulate further interest and prevent boredom.

5. **Licences for the feedlot in Australia**
   Government agriculture departments and local shire councils have specific requirements for environmental aspects of lot feeding. These include effluent management, site location and water derivation. Before lot feeding, consult the appropriate local authorities for approval. The predisposition of a site to environmental and community problems, particularly those caused by groundwater contamination, soil erosion and dust pollution, is a vital consideration in assessing its suitability for lot feeding.

6. **Cleaning the feedlot pad**
   The pen surface should be cleaned between each new lot of animals, and the manure stockpiled and managed according to recommended procedures.

Further reading

- Bell AK, Shands CG, and Hegarty RS (1998), *Feedlotting lambs*, Agnote DAI/42, NSW Agriculture, Armidale.
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- Flint M and Murray PJ (2002), *Facilities guide for lot feeding goats*, published on DPI's website and DPI's PrimeNotes CD-ROM.
- Kondinin Group (1998), Lot feeding lambs research report, *Farming Ahead* 76: 64–77. Kondinin Group, Cloverdale.
- Nolan C and Dunlop L (1996), *Lamb feedlotting in Queensland*, Queensland Department of Primary Industry, Brisbane.
- Primary Industries and Resources SA (1997), *Feeding sheep*, Primary Industries and Resources SA, Port Lincoln.

Tool 7.9 – Forage budgeting

- Stocktake basic forage budget

	Start date	1 April 2018
	Property name	'Upsen Downs'
	Paddock name	'Goat'
A	Paddock area (ha)	100ha
B	Stock number (DSE)	100 DSE (100 mixed goats)
	End date	30 June 2018
C	Grazing days	90 days
D	Starting pasture yield (kg DM/ha)	2,000kg
E	% unpalatable	10%
F	Unpalatable (kg DM/ha) [DxE]	(2,000kg x 10%) = 200kg
G	Desired residual (kg DM/ha)##	700kg
H	Detachment kg/ha [Dx15%] (Trampling, frost damage, etc.)	(2,000kg x 15%) = 300kg
I	Anticipated growth (kg DM/ha)	200kg
J	Total usable pasture (kg DM/ha) [D-F-G-H+I] (2,000-200-700-300+200) = 1,000kg DM/ha	
K	Usable pasture in paddock (kg) [JxA] (1,000kg x 100ha) = 10,000kg	
L	Pasture eaten for period (kg) [BxCx1.1] (100 DSE's x 90 days x 1.1kg DM) = 9,900kg	
	If L is less than K, there is enough feed for the period.	
	Number of days feed will last [K/(Bx1.1)] (10,000kg / (100 DSE x 1.1kg) = 91 days	

Note: 40kg dry goat equals 0.9 DSE.

1 DSE eats 1.1kg dry matter (DM)/head/day.

Minimum residual ground cover is 50-70% to optimise water infiltration and minimise soil loss.

Residual pasture should be at least in phase 2 growth for quick response and worm management.

Tool 7.10 – Recommendations for energy requirements for goats

Recommendations for energy requirements of goats, as discussed in *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids* (2007), are based primarily on reports summarised by Sahlu and co-workers of Kika de la Garza Institute for Goat Research, Langston University, (2004). The formulae for both the metabolic energy and metabolic protein requirements for a large range of breeds and production levels are included in the tables below.

In the below information the descriptor 'indigenous' refers to neither meat nor dairy, not including Angora > 18 months of age. It would be equivilent to the Australian rangeland goat.

Table T7.10-1: Formulae for metabolic energy and metabolic protein requirements of various classes of goats

	Pre-weaning	Growing meat ≥ 50% Boer	Growing dairy	Growing indigenous	Mature indigenous & dairy	Angora	Units
ME (m)	485	489	580	489	462	483	kJ/kg BW0.75
ME (g)	13.4	23.1	23.1	19.8	28.5	37.2	kJ/g ADG
ME (l)	–	–	–	–	5224	5224	kJ/kg (4% FCM)
ME (f)	–	–	–	–	-	157	kJ/g ADG
MP (m)	–	3.07	3.07	3.07	Depends on DMI	3.35	g/kg BW0.75
MP (g)		0.404	0.29	0.29	–	0.281	g/g ADG
MP (l)	–	–	–	–	1.45	1.45	g/g milk protein
MP (f)	–	–	–	–	-	1.65	g/g

(m) maintenance, (g) = growth, (l) = lactation, (f) fibre, BW0.75 = Metabolic Body Weight

ADG = Average Daily Gain, 4% FCM = Fat Corrected Milk at 4% Fat

Dairy = Saanen, Alpine, Damascus, Norwegian, Swedish landrace and dairy crossbreeds

Growing = post weaning to 18 months of age: Meat ≥50% Boer.

◆ ME requirements for adult goats by breed, weight and weight gain – megajoules

Table T7.10-2: Metabolisable energy requirements of adult goats – dairy, meat and indigenous

Average daily gain (g/day)	Body weight (kg)					
	20	30	40	50	60	70
Dairy goats						
Male castrates and does						
0	4.7	6.4	8.0	9.4	10.8	12.1
20	5.3	7.0	8.5	10.0	11.4	12.7
40	5.9	7.6	9.1	10.6	12.0	13.3
60	6.5	8.1	9.7	11.1	12.5	13.8
80	7.0	8.7	10.3	11.7	13.1	14.4
Intact males						
0	5.5	7.4	9.2	10.8	12.4	14.0
20	6.0	8.0	9.7	11.4	13.0	14.5
40	6.6	8.5	10.3	12.0	13.6	15.1
60	7.2	9.1	10.9	12.6	14.1	15.7
80	7.7	9.7	11.5	13.1	14.7	16.2
Meat and indigenous goats						
Male castrates and does						
0	4.0	5.4	6.7	8.0	9.1	10.2
20	4.6	6.0	7.3	8.5	9.7	10.8
40	5.1	6.6	7.9	9.1	10.3	11.4
60	5.7	7.1	8.4	9.7	10.8	11.9
80	6.3	7.7	9.0	10.2	11.4	12.5
Intact males ME (m)						
0	4.6	6.2	7.7	9.1	10.5	11.8
20	5.2	6.8	8.3	9.7	11.1	12.3
40	5.7	7.4	8.9	10.3	11.6	12.9
60	6.3	7.9	9.9	10.9	12.2	13.5
80	6.9	8.5	10.0	11.4	12.8	14.0

◆ Maintenance requirements of lactating goats for diets of differing energy densities

Table T7.10-3: Maintenance requirements of lactating goats for diets of differing energy densities

Megajoules	Body weight (kg)					
	20	30	40	50	60	70
7	5.2	7	8.7	10.2	11.8	13.2
9	4.9	6.6	8.2	9.7	11.1	12.4
11	4.6	6.2	7.7	9.2	10.5	11.8
13	4.4	5.9	7.4	8.7	10.0	11.2

◆ ME requirements for grower goats by breed, weight and weight gain

Table T7.10-4: Metabolisable energy requirements of grower goats

Grams/day	Body weight (kg)								
	15	20	25	30	35	40	45	50	55
Meat goats									
Wethers and does									
0.0	3.5	4.3	5.1	5.8	6.5	7.2	7.9	8.5	9.1
50.0	4.6	5.4	6.2	7.0	7.7	8.4	9.0	9.7	10.3
100.0	5.8	6.6	7.4	8.1	8.8	9.5	10.2	10.8	11.5
150.0	6.9	7.7	8.5	9.3	10.0	10.7	11.3	12.0	12.6
200.0	8.1	8.9	9.7	10.4	11.1	11.8	12.5	13.1	13.8
250.0	9.2	10.1	10.8	11.6	12.3	13.0	13.6	14.3	14.9
300.0	10.4	11.2	12.0	12.7	13.4	14.1	14.8	15.4	16.1
Intact males									
0.0	4.0	5.0	5.9	6.7	7.6	8.4	9.1	9.9	10.6
50.0	5.2	6.1	7.0	7.9	8.7	9.5	10.3	11.0	11.8
100.0	6.3	7.3	8.2	9.1	9.9	10.7	11.4	12.2	12.9
150.0	7.5	8.4	9.3	10.2	11.0	11.8	12.6	13.4	14.1
200.0	8.6	9.6	10.5	11.4	12.2	13.0	13.8	14.5	15.2
250.0	9.8	10.8	11.7	12.5	13.3	14.1	14.9	15.7	16.4
300.0	10.9	11.9	12.8	13.7	14.5	15.3	16.1	16.8	17.6

Grams/day	Body weight (kg)								
	15	20	25	30	35	40	45	50	55
Dairy goats									
Wethers and does									
0.0	4.1	5.1	6.0	6.9	7.7	8.5	9.3	10.1	10.8
50.0	5.2	6.2	7.2	8.0	8.9	9.7	10.5	11.2	12.0
100.0	6.4	7.4	8.3	9.2	10.0	10.8	11.6	12.4	13.2
150.0	7.6	8.5	9.5	10.3	11.2	12.0	12.8	13.6	14.3
200.0	8.7	9.7	10.6	11.5	12.3	13.5	13.9	14.7	15.5
250.0	9.9	10.9	11.8	12.7	13.5	14.3	15.1	15.9	16.6
300.0	11.0	12.0	12.9	13.8	14.7	15.5	16.3	17.0	17.8
Intact males									
0.0	4.8	5.9	7.0	8.0	9.0	9.9	10.8	11.7	12.6
50.0	5.9	7.1	8.1	9.2	10.1	11.1	12.0	12.9	13.8
100.0	7.1	8.2	9.3	10.3	11.3	12.2	13.1	14.0	14.9
150.0	8.2	9.4	10.4	11.5	12.4	13.4	14.3	15.2	16.1
200.0	9.4	10.5	11.6	12.6	13.6	14.5	15.5	16.3	17.2
250.0	10.5	11.7	12.8	13.8	14.8	15.7	16.6	17.5	18.4
300.0	11.7	12.8	13.9	14.9	15.9	16.9	17.8	18.7	19.5
Indigenous goats									
Wethers and does									
0.0	3.5	4.3	5.1	5.8	6.5	7.2	7.9	8.5	9.1
50.0	4.4	5.2	6.1	6.8	7.5	8.2	8.9	9.5	10.1
100.0	5.4	6.3	7.0	7.8	8.5	9.2	9.8	10.5	11.1
150.0	6.4	7.3	8.0	8.8	9.5	10.2	10.8	11.5	12.1
200.0	7.4	8.2	9.0	9.8	10.5	11.2	11.8	12.5	13.1
250.0	8.4	9.2	10.0	10.8	11.5	12.1	12.8	13.5	14.1
300.0	9.4	10.2	11.0	11.7	12.5	13.1	13.8	14.5	15.1
Intact males ME (m)									
0.0	4.0	5.0	5.9	6.7	7.6	8.4	9.1	9.9	10.6
50.0	5.0	6.0	6.9	7.7	8.6	9.4	10.1	10.9	11.6
100.0	6.0	7.0	7.9	8.7	9.5	10.3	11.1	11.9	12.6
150.0	7.0	7.9	8.9	9.7	10.5	11.3	12.1	12.9	13.6
200.0	8.0	8.9	9.8	10.7	11.5	12.3	13.1	13.8	14.6
250.0	9.0	9.9	10.8	11.7	12.5	13.3	14.1	14.8	15.6
300.0	10.0	10.9	11.8	12.7	13.5	14.3	15.1	15.8	16.6

◆ ME requirements for milk production for all breeds by yield

Table T7.10-5: Metabolisable energy requirements for milk of different fat content

Milk yield (kg)	Milk Fat %				
	3	3.5	4	4.5	5
1	4.3	4.6	4.9	5.3	5.6
2	8.6	9.2	9.9	10.5	11.2
3	12.9	13.8	14.8	15.8	16.7
4	17.2	18.5	19.8	21	22.3
5	21.5	23.1	24.7	26.3	27.9
6	25.7	27.7	29.6	31.6	33.5
7	30.0	32.3	34.6	36.8	39.1

◆ ME requirements for suckling goats for all breeds by growth rate

Table T7.10-6: Metabolisable energy requirements for suckling goats

Average daily gain (g/day)	Body weight (kg)								
	2	4	6	8	10	12	14	16	18
Wethers and doelings ME (m)									
Megajoules									
0.0	0.8	1.3	1.7	2.1	2.5	2.9	3.2	3.6	3.9
50.0	1.4	1.9	2.4	2.8	3.2	3.6	3.9	4.3	4.6
100.0	2.1	2.6	3.1	3.5	3.9	4.2	4.6	4.9	5.3
150.0	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.6	5.9
200.0	3.4	3.9	4.4	4.8	5.2	5.6	5.9	6.3	6.6
250.0	4.1	4.6	5.1	5.5	5.9	6.2	6.6	6.9	7.3
300.0	4.8	5.3	5.7	6.2	6.5	6.9	7.3	7.6	7.9
Intact males ME (m)									
Megajoules									
0.0	0.9	1.5	2.0	2.5	2.9	3.4	3.8	4.2	4.6
50.0	1.5	2.1	2.7	3.2	3.6	4.0	4.4	4.8	5.2
100.0	2.2	2.8	3.3	3.8	4.3	4.7	5.1	5.6	5.9
150.0	2.9	3.5	4.0	4.5	4.9	5.4	5.8	6.2	6.6
200.0	3.6	4.2	4.7	5.2	5.6	6.0	6.5	6.9	7.2
250.0	4.2	4.8	5.3	5.8	6.3	6.7	7.1	7.5	7.9
300.0	4.9	5.5	6.0	6.5	7.0	7.4	7.8	8.2	8.6

Tool 7.11 – Metabolic protein requirements

The following tables relate to the metabolisable protein requirements for maintenance and gain of growing goats.

The protein tables which follow have been sourced from a paper by Luo J, 'Metabolisable protein requirements for maintenance and gain of growing goats', *Small Ruminant Research*, Volume 53, Issue 3, July 2004, pages 309–32.

Table T7.11-1: Metabolisable protein for maintenance MP(m) of mature meat, dairy and indigenous goats at varying dry matter intakes expressed as a % of body weight

DM intake (% BW)	Body weight (kg)					
	20	30	40	50	60	70
1	16	23	29	35	41	46
2	22	31	40	48	57	65
3	27	39	50	62	73	84
4	32	47	61	75	89	103
5	38	55	72	88	105	121
6	43	63	82	102	121	140

Table T7.11-2: Metabolisable protein requirements for maintenance and gain of growing meat, dairy and indigenous goats

Average daily gain (g/day)	Body weight (kg)								
	15	20	25	30	35	40	45	50	55
MP(m)									
0.0	23	29	34	39	44	48	55	58	60
MP(m) + MP(g)									
Meat									
50	44	49	55	60	64	69	74	78	82
100	64	69	75	80	85	89	94	98	102
150	84	90	95	100	105	109	114	118	123
200	104	110	115	120	125	130	134	139	143
250	124	130	135	140	145	150	154	159	163
Dairy and indigenous									
50	38	43	49	54	59	63	68	72	77
100	52	58	63	68	73	78	82	87	91
150	67	73	78	83	88	92	97	101	106
200	81	87	92	97	102	107	111	116	120
250	96	102	107	112	117	121	126	130	135

MP(m) was 3.07g/kg BW0.75 for all biotypes of growing goats. MP(g) was 0.404 and 0.290g/g ADG for meat and other (dairy and indigenous) goats.

Table T7.11-3: Metabolisable energy and protein requirements of goats during pregnancy

Birth weight (kg)	Days pregnant	ME (MJ/day)			MP (g/day)		
		One kid	Two kids	Three kids	One kid	Two kids	Three kids
2	91–100	0.1	0.3	0.4	4.1	5.8	8.8
	101–110	0.7	1.3	1.7	9.8	17.1	23.4
	111–120	1.2	2.1	2.8	14.6	25.6	35.1
	121–130	1.7	2.8	3.8	19.5	34.3	45.9
	131–140	2.1	3.4	4.6	24.2	41.8	55.7
	141–150	2.5	3.8	5.1	27.6	45.9	61.3
3	91–100	0.2	0.4	0.6	6.3	8.5	13.2
	101–110	1.0	1.9	2.6	14.8	25.6	35.1
	111–120	1.8	3.1	4.3	22.1	38.4	52.6
	121–130	2.5	4.2	5.6	29.3	51.6	68.7
	131–140	3.1	5.1	6.9	36.2	62.6	83.5
	141–150	3.7	5.7	7.6	41.4	68.7	91.8
4	91–100	0.2	0.5	0.8	8.2	11.6	17.6
	101–110	1.4	2.5	3.5	19.7	34.2	46.9
	111–120	2.4	4.1	5.7	29.3	51.2	69.9
	121–130	3.3	5.6	7.5	39.2	68.7	91.8
	131–140	4.2	6.9	9.2	48.3	83.5	111.5
	141–150	4.9	7.6	10.2	55.2	91.8	122.5
5	91–100	0.3	0.6	1.1	10.2	14.3	21.8
	101–110	1.7	3.2	4.3	24.6	42.7	58.5
	111–120	3.0	5.2	7.1	36.6	64.0	87.8
	121–130	4.2	7.0	9.4	49.0	85.9	114.6
	131–140	5.2	8.6	11.4	60.3	104.4	139.3
	141–150	6.1	9.5	12.7	68.9	114.6	153.0

Table T7.11-4: Estimates of metabolisable protein (MP; g/day) requirements of lactating goats

Milk yield (kg)	Milk protein %					
	2.5	3	3.5	4	4.5	5
1	36	44	51	58	65	73
2	73	87	102	116	131	145
3	109	131	152	174	196	218
4	145	174	203	232	261	290
5	181	218	254	290	326	363
6	218	261	305	348	392	*435*
7	254	305	355	406	*457*	*508*

Table T7.11-5: Metabolisable energy (ME; MJ/day) and protein (MP; g/day) requirements of Angora goats

Body weight (kg)	Tissue gain (g/day)	ME (m)	Clean fibre growth rate (g/day)				
			5	10	15	20	25
ME (m) (Maintenance)							
15		3.61					
25		5.29					
35		6.81					
45		8.22					
MEtg + MEfg (Tissue and fibre)							
	0		0.79	1.57	2.36	3.14	3.93
	25		1.72	2.5	3.29	4.07	4.86
	50		2.65	3.43	4.22	5	5.79
		MP (m)					
MP (m) (Maintenance)							
15		25.5					
25		37.5					
35		48.2					
45		58.2					
MPtg + MPfg (Tissue and fibre)							
	0		8.3	16.5	24.8	33	41.3
	25		15.3	23.5	31.8	40	48.3
	50		22.3	30.6	38.8	47.1	55.3

Tool 7.12 – Composition of some common forages

Table T7.12-1: Composition of some common forages (per kg DM) (from AFRC 1993 Appendix 1 and various NSW sources where indicated)

Forage	ME(MJ)	FME(MJ)	EE(g)	CP(g)	ERDP2(g)	DUP2(g)	ERDP5(g)	DUP5(g)	ERDP8(g)	DUP8(g)
Temperate grass	12.6	11.7	25	190	159	20	134	42	117	58
early vegetative	11.6	10.7	25	150	118	17	103	30	92	40
late vegetative	9.5	8.8	19	120	85	22	72	33	64	40
early flowering	7.5	6.9	16	97	64	23	52	33	45	40
in seed										
Hays										
lucerne	8.5	8.1	13	183	141	26	131	34	123	40
lucerne (NSW)	9.1			169						
clover (NSW)	8.5			125						
oaten (NSW)	8.7			88						
Silage										
maize	11.3	9.0	32	98	69	11	67	13	65	14
maize (NSW)	8.7			75						
sorghum (NSW)	7.9			69						
oats (NSW)	6.9			56						
Straw										
wheat (NSW)	6.1			19						
Edible Trees (NSW)										
mulga	5.8			128						
kurrajong	7.7			96						
wilga	8.0			142						
Grains										
wheat (NSW)	13.1			150						
triticale (NSW)	13.0			169						
barley (NSW)	12.2			113						
sorghum (NSW)	12.5			131						
sorghum (NSW)	11.1			119						
oats (NSW)	12.1	10.7	41	105	83	6	82	8	81	9
oats	12.9			350						
lupins (NSW)	14.2	10.5	104	342	288	22	251	44	226	59
lupins	11.1	8.8	66	375	268	70	222	109	195	132
cottonseed meal	11.6			450						
molasses (NSW)	12.6			40						
urea	0	0	0	2,600	2,080	0	2,080	0	2,080	0

ME: metabolisable energy
FME: fermentable metabolisable energy
EE: ether extract, an estimate of fat content
CP: crude protein
ERDP: effective rumen degradable dietary protein with the potential to be captured by rumen microbes at rumen digesta outflow rates of 2%, 5% or 8% per hour (feeding levels 1, 2 or 3)
DUP: digestible undegraded rumen protein

Tool 7.13 – High-energy feeds

◆ Barley

DM:	88–90%
Energy:	12.5–13 MJ/kg
Protein:	11–14%
Fat:	2.2%
Fibre:	3.37%

» Storage:

- stores well but must be kept dry
- should be free of stalks and stubble on arrival
- density should be around 620–650 gms per litre
- if stored for more than six months, should be treated for weevils with Phostoxin
- best stored in a silo
- potential for mouse and rat problems – botulism, salmonella and leptospirosis risk
- must be <12% moisture.

» Availability:

- winter-growing crop – harvested in Nov–Dec
- can be purchased year round but price increases towards end of the year
- most suitable grain for lot feeding, as wheat and corn are usually too expensive and no sorghum grown.

» Processing:

- not needed
- do not over-process or grind too fine in hammer mill.

» Importance:

- barley will always be needed in most rations to raise the energy density of the ration
- provision and planning is essential to ensure supplies are available all year round if needed
- barley will never be a really cheap commodity to purchase and its inclusion in the ration will increase the overall price of the ration.

◆ Corn

DM:	>85%
Energy:	13.6%
Protein:	9%
Fat:	4.06%
Fibre:	2.29%

» Storage:

- same as barley – must be stored dry
- long-term storage best in silo and treated for weevils
- density and moisture should be checked on arrival.

» Availability:

- excellent source of energy but is usually too costly for use in feedlots
- summer-growing cereal crop and would be available from late summer
- usually price is prohibitive.

» Processing:

- can be fed whole
- best rolled or hammer milled
- do not over-process.

» Importance:

- should be used if price is acceptable – usually competition from poultry
- low in protein
- check price and availability at the end of summer.

◆ Wheat

DM:	89–91%
Energy:	13.3 MJ/kg
Protein:	12–15%
Fat:	2.34%
Fibre:	3.66%

» Storage:

- must be stored dry
- same as other grains – best stored in silo over long periods for protection from vermin and weevils
- density and moisture must be checked on arrival
- should be free of stalk and foreign material such as stones and other plant matter.

» Availability:

- winter growing cereal crop – available from December–March but stored year round
- usually too expensive for inclusion in ration
- used for human consumption
- occasionally broken grain – low protein or downgraded product may be available.

» Processing:

- same as other grains.

» Importance:

- extremely good source of energy – better than barley, but usually out of price range in feedlot
- if price is right – always consider purchasing.

◆ Cottonseed

DM:	89%
Energy:	13.6 MJ/kg
Protein:	24.4%
Fat:	17.5%
Fibre:	25.6%

» Storage:

- long-term storage – best kept in shed but can be stored under tarp in open
- will not flow through a grain auger
- best moved with an elevator or front-end loader.

» Availability:

- cotton is a summer-growing crop – cottonseed is available in April–May
- may be available early in New Year but prices usually increase
- ensure enough storage is available and enough cottonseed is secured for a whole season
- check for pesticide residues.

» Processing:

- no processing is required
- add whole cottonseed to ration.

» Importance:

- cottonseed is an extremely valuable stock feed for a feedlot ration and, if price is suitable, it should be made a priority to obtain
- stores well, does not need processing, and is high in energy, protein and fibre
- usually cannot be added at more than 10–15% of ration due to high fat content – fat in ration should = <6.0%.

◆ Molasses

DM:	75–80%
Energy:	11.34 MJ/kg
Protein:	10%
Fat:	1.3%
Fibre:	0%

» Storage:

- in a tank, preferably with heating capabilities in colder regions
- molasses is a very dense liquid – almost 1.5 times as dense as water – so tank should have strong walls
- stores very well – little waste
- ensure tap is always properly turned off.

» Availability:

- may not be available locally
- has to be transported from sugar cane-growing areas
- available year round but need to organise a contract.

» Processing:

- may need heating in winter prior to inclusion in ration
- best sprayed onto ration as mixer is going.

» Importance:

- good source of sulphur
- very desirable to include in the ration
- fairly cheap source of high-energy, but cannot be included at levels much greater than 10% due to possible diarrhoea effects
- very good palatability and masks odour of ratio making ration changes much easier and less noticeable.

◆ Lupins

DM:	87–90%
Energy:	12 MJ/kg (depends on variety)
Protein:	15%
Fat:	6%
Fibre:	5%

» Storage:

- must be stored dry
- in silo, or bunk
- check bulk density and presence of grub damage, other seeds, mould and foreign material.

» Availability:

- summer-growing crop
- may become available when new product is being harvested
- usually too expensive but will depend on supply, freight costs and proximity.

» Processing:

- processing not required
- can be rolled or hammer milled
- can be soaked overnight and fed whole – if soaked, ensure all wet product is used every day.

» Importance:

- excellent source of protein and high-energy
- routinely included in ration if not too expensive
- should be stored if price is right.

Tool 7.14 – Medium-energy feeds

◆ Brewer's grain

DM:	21–28%
Energy:	10.58 MJ/kg
Protein:	24%
Fat:	1.92%
Fibre:	7.8%

» Storage:

- best used fresh and will last a week or two fresh
- dry matter increases with age as water drains off
- if kept too long, will go sour and mouldy
- can be ensiled immediately with mill run – check DM first and make silage at 40% DM.

» Availability:

- available all year round – by-product of beer production
- prices fluctuate – usually cheapest at beginning of summer months when beer production is highest
- competition from dairy farmers
- always compare on a dry matter basis with barley.

» Processing:

- feed in current form
- regularly check DM and adjust ration accordingly.

» Importance:

- important source of medium density energy
- high in protein
- can be fed up to 30% of ration
- high moisture content limits high inclusion in ration
- very palatable and safe form of carbohydrate.

◆ Corn silage

DM:	27–38% (variable)
Energy:	10 MJ/kg
Protein:	8.3%
Fat:	2.10%
Fibre:	20%

» Storage:

- best stored in bunk, clamp or harvest store
- must be completely sealed from outside air
- must be packed tight to press out air
- best treated with enzyme at time of storage
- should be sealed as soon as possible to improve quality

» Availability:

- made at end of summer (Feb–May)
- may be purchased close by, but freight is usually a big cost – will last only three days maximum once transported
- cannot be purchased and then repacked at feedlot.

» Processing:

- finely chopped silage is the best, as the air can be excluded much more readily
- best made at 35% dry matter.

» Importance:

- cheap source of medium-energy and fibre
- always low in protein – non-protein nitrogen is needed to balance ration
- very palatable and good base for ration
- not high enough in energy to be used alone in ration
- quality can be maintained with storage, fire proof and high tonnage achieved if produced on site
- best available source of high volumes of feed on farm.

◆ Lucerne hay

DM:	88–92%
Energy:	9 MJ/kg
Protein:	18.7%
Fat:	2.6%
Fibre:	28%


Good quality – leafy


Poor quality – mainly stalk

» Storage:

- keep dry – store in shed
- inflammable – check it's not being stored too moist (do DM evaluation on purchase – can self-ignite if shedded wet)
- goes mouldy if too wet when stored.

» Availability:

- available all year round but price fluctuates markedly
- best quality generally in spring – summer-made hay can suffer leaf shatter due to low humidity when made (very stalky)
- winter growth is slow and price is high – more likely to be spoilt by winter rain
- autumn hay also reasonable quality.

» Processing:

- best chopped up in mixer or chaffed
- large quantities cause problems in mixer.

» Importance:

- valuable for use in starter ration as highly palatable and readily acceptable
- important for treatment of stock with diarrhoea
- high protein and calcium, medium-energy and good fibre
- usually too expensive to include as energy source
- always evaluate on leaf content – colour varies with age.

◆ Mill run

DM:	90%
Energy:	10.96 MJ/kg
Protein:	13.5%
Fat:	5%
Fibre:	9.5%

» Storage:

- best stored loose in bunk
- must be kept dry at all times
- need vermin and bird control.

» Availability:

- by-product of wheat and flour milling
- available all year round
- quality quite variable depending on type of flour mill and initial quality of wheat
- prices fluctuate during season – cheapest in late autumn and early summer just after wheat harvest.

» Processing:

- feed in present state
- it is already finely processed.

» Importance:

- excellent source of energy and dry matter
- fine processing limits inclusion in ration above 20%
- very good base for inclusion in vegetable by-product silage production
- usually relatively cheap compared to grains and should always be considered in the ration composition.

Tool 7.15 – Low energy density feeds (sources of fibre and dry matter)

◆ Barley straw

DM:	91%
Energy:	6–7 MJ/kg
Protein:	4.4%
Fat:	1.9%
Fibre:	41.5%

» Storage:

- comes in small bales around 15kg or large rectangular bales weighing 250kg or more
- must be kept dry but can be made into a stack and covered with a tarp in the open
- extreme fire hazard.

» Availability:

- best acquired immediately after barley harvest in late November–December
- higher feed value than wheat stubble therefore usually more expensive
- fairly uniform product – always purchase on weight and not by the bale.

» Processing:

- best chopped up by mixer and added straight into ration
- ensure twine is completely removed from bale.

» Importance:

- valuable source of fibre
- levels of inclusion over 5% drastically affect energy density of ration
- check value against other sources of fibre, e.g. wheat stubble, cotton hulls etc.
- very palatable source of fibre.-

Cotton hulls

DM:	91%
Energy:	6.35 MJ/kg
Protein:	8%
Fat:	1.7%
Fibre:	54.7%

» Storage:

- store under cover
- very low density and takes up a lot of shed space
- high fire risk.

» Availability:

- usually available all year round
- by-product of the ginning process
- most abundant after cotton harvest.

» Processing:

- add to feed in current state – no processing required.

» Importance:

- excellent source of fibre in a wet ration
- usually more expensive than straw
- always a possible problem of chemical contamination and must be tested if origin unknown
- takes up a lot of shed space.

◆ Wheat straw

DM:	91%
Energy:	6 MJ/kg
Protein:	4.4%
Fat:	1.9%
Fibre:	41.5%

◆ Storage:

- presented in small bales or large round or rectangular bales
- keep dry and it will store indefinitely
- highly flammable.

◆ Availability:

- common around November–January after wheat harvest
- usually cheaper than barley stubble hay.

» Processing:

- straight into mixer
- ensure all baler twine is removed.

» Importance:

- substitute for barley stubble but not as palatable due to higher lignin content and higher per centage of stalk
- higher lignin content and less leaf than barley straw
- need to have either barley or wheat stubble on hand at all times to ensure adequate fibre in diet.

Tool 7.16 – High-protein feed sources

◆ Cottonseed meal

DM:	90%
Energy:	11.34 MJ/kg
Protein:	46%
Fat:	3%
Fibre:	13%

» Storage:

- keep dry at all times – will go mouldy when wet
- store in shed loose.

» Availability:

- usually available all year round with notice
- most abundant after cotton season in April–May
- supplied loose; one tonne bulka bags or 20kg bags.

» Processing:

- none required.

» Importance:

- excellent source of protein with good 'bypass' protein as well
- especially good for young growing goats and lactating does
- can be fed out as is twice/week in long troughs to avoid bullying
- may contain varying amounts of gossypol – calcium levels need to be adequate as gossypol binds with calcium.-

◆ Sunflower meal

DM:	93%
Energy:	9.83 MJ/kg
Protein:	38%
Fat:	2.9%
Fibre:	23%

» Storage:

- store in bags or loose in bunk
- keep dry – ensure no leaks in roof.

» Availability:

- seems to be available all year round but prices increase towards end of spring – early summer
- sunflowers are grown in summer and harvested at the end of the season
- meal is a byproduct of sunflower oil extraction.

» Processing:

- presented as a finely ground meal
- feed as presented.

» Importance:

- important source of additional protein
- need to compare in price on a crude protein per centage with cottonseed meal
- lower in crude protein than cottonseed meal, also not as high in energy or bypass protein.

Tool 7.17 – How to calculate the required energy supplement

It is important to calculate how much energy your livestock are likely to realistically and practically receive from a supplement. The following approaches will help you to do this.

Example 1:
Suppose you have a mob of does (average weight 50kg) with kids at foot (singles) and you want to consider feeding a ration of 50% barley and 50% lucerne hay. The kids are 5kg and you are targeting gains of 150g/day.

Question:
a) How much do I feed?
b) Do I need to add other ingredients?

◆ Approach:

Refer to tables in Tool 7.10 and Tool 7.11 for this section.

1. **Determine the metabolisable energy (ME)** requirements of the doe.
   a. The kids – **Table T7.10-6** – a 5kg suckling goat growing at 150g/day requires approximately 3.5 MJ/day (a 4kg kid growing at 150g/day = 3.3 and 6kg kid at 150g/day = 3.7).
   b. How much milk does a kid need to drink to obtain 3.5 MJ? The energy in milk varies according to fat content but on average, one litre of milk provides 2.88 MJ. Therefore, the doe will need to produce 3.5/2.88 = 1.22 litres of milk.
   c. The does – The ME required for maintenance of a 50kg lactating doe on a diet of 9 MJ/kg – **Table T7.10-3** - 9.7 MJ.
   d. The extra ME required by the doe for milk – **Table T7.10-5**– one litre of 4.5% milk fat requires 5.3 MJ therefore 1.22 litres will require 6.46 MJ.
   e. The total ME requirements therefore are approximately 9.7 MJ + 6.46 MJ = **15.7 MJ** (assuming the kid is still totally reliant on the doe for milk).
2. **Determine the metabolic protein (MP)** requirements of the doe – use Tool 7.10 and 7.11.
   a. For maintenance – 58g/day.
   b. For milk – The MP for one litre of milk with 4% milk protein = 58g, therefore the requirement for 1.22 litres of milk = 70.76g/day.
   c. The total MP requirement = 58 + 70.76 = **129g/day**.
   d. Crude Protein content of the ration – conversion factor is 0.7, so CP = 129/0.7 = **184.2g** CP
3. **The ME and CP value of the ration**

- Barley G2 DM = 90%, ME = 12.59 MJ/kg, CP = 10.5%, eNDF = 34% and NDF = 20.11
- Lucerne DM = 90%, ME = 8.74 MJ/kg, CP = 18.7%, eNDF = 92% and NDF = 47.1
- Ration DM = 90%, ME = 10.66 MJ/kg, CP = 14.6% eNDF = 63% and NDF = 33.6

4. The dry matter intake (DMI)/day of the doe

- See **Table** in Tool 7.2: Estimate of voluntary DM (kg/day) by lactating goats in a pen/stall.
- 50kg doe giving one litre/day of milk on a 11 MJ/kg ration and 0kg/day average daily gain = 1.37kg/day. The same goat giving two litres of milk/day = 1.77kg/day, therefore the estimated DMI of a doe giving 1.22L of milk/day = (1.77 – 1.37) x 0.22 + 1.37 = 1.46kg. This value is derived for a diet with an M/D of 11 MJ/kg, but for a diet of only 10.66, it would be marginally more than this – **1.49kg**

5. Daily ME and CP intake by the doe

- ME = 1.49 x 10.66 MJ = 15.88 MJ and CP = 1.49 x 146g = 218g CP

6. Is the diet adequate?

- Energy wise, the estimated 15.88 MJ being provided in the ration is just above the 15.7 MJ that was calculated above and the protein being supplied of 218g exceeds the requirement calculated to be 184.2g of CP.
- Finally, the eNDF supplied by this ration is 63% x 33.6 = 21.17. When this is applied to the formula pH = 5.425 + (.04229 x eNDF) = 6.32 which is well above the minimum requirement of 6, therefore there should be no issues with acidosis.

Example 2:
Suppose you have some entire male goats that weigh only 18–22kg when harvested, and you wish to determine if it will be cost-effective to feed them for 50 days to meet a target weight. The local feed-mixing company has a grower ration available at $400/tonne and it has a ME value of 11 MJ/kg and CP content of 15%.

Assumptions:

- it is October so there is no need to worry about winter stasis
- DM% of the ration is 90%
- you need the goats to grow at 200g/day.

1. The actual cost/tonne of the ration. $400/tonne $400/tonne ÷ 0.90 = $444.44/tonne DM.
2. If they grow at 200g/day for 50 days, they will increase in body weight by 10kg – the average weight of the goats during their time on feed will be (30 + 20)/2 = 25kg.
3. Table 8: Intact male rangeland (indigenous) growing at 150g/day = 9.8 MJ.
4. Amount of feed required on average per day = 9.8/11 = 0.89kg/day.
5. Quantity of protein in ration being supplied daily = 0.89 x 150g = 133.63.
6. Table 12: Quantity of MP required daily for 200g/day avergage daily gain (ADG) and average weight of 25kg for indigenous male goat = 92g.
7. Table 16: Apply correction factor of 0.7 to the MP value derived in 6.
   Above = 92/0.7 = 131g, therefore the ration has adequate protein.
8. Daily feed cost to gain 200g/day = 0.89 x $444.44/1000 = $0.395/day for feed to gain 0.2kg or a Feed Cost of Gain of $1.97/kg.

The above calculations all seem rather complex but it is straight forward once the correct approach is taken. While it won't be 100% accurate, as there as some estimates that need to be included, it will give you confidence that you are in the ball park regarding your ration formulation.

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October 2018