Lecture 19: Nutrition for Sheep Production

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Learning objectives
On completion of this topic you should be able to:

- list the key components of diets for sheep
- understand the importance of the rumen and its microbes in digesting feed components
- list the key end-products of digestion of dietary materials in the rumen
- list the principal sources of metabolisable energy and amino acids available to the sheep tissues
- define protein quality (amino acid composition) and the factors affecting protein requirements for growth and milk production in sheep
- understand the factors affecting maintenance/production energy requirements of younger and older sheep
- understand the importance of nutrition for ewes in the pre-mating period and during pregnancy and lactation
- outline the nutritional requirements of pasture-fed and feedlot lambs.

Key terms and concepts
Escape or bypass protein; essential amino acids; cellulose and lignin; gross energy; metabolisable energy; energy for maintenance/production; metabolisable protein; protein turnover; protein regeneration cycle; 'flushing; 'transition period'; DCAB; anti-nutritional factors; urinary calculi and 'water belly'; M/D; acidosis weaner 'ill thrift'.

19.1 Introduction
The level of production of meat sheep seldom reaches their genetic potential, so production is generally less than ideal. This is often due, for example, to inadequate levels of nutrition to meet the changing needs of ewes and lambs at different stages of the production cycle or to ameliorate animal health or other problems. Often management issues that lower production are inter-active; so, for example, inadequate nutrition may exacerbate health problems, or climatic extremes may affect feed intake and nutrient supply.

The nutritional needs of livestock are often categorised as energy, protein, minerals and vitamins; adequate supplies of clean water are also needed. An animal's requirements for each of these dietary components, and the ratios of one to another, depend on its live weight, stage of maturity and physiological state (growing, pregnant, lactating). Thus dietary management is about matching feeds with (nutritional) needs. In most situations, energy or protein are the key nutritional components that limit sheep production, although vitamins and minerals can be limiting in lambs. Anti-nutritional factors in the diet should also be kept to a minimum.

How well any feed will meet an animal's requirements (feed quality) depends on how efficiently the energy and protein components in the feed (often a forage or a grain or vegetable meal supplement) are digested in the gut and absorbed into the bloodstream, and also how effectively the absorbed digestion products are taken up by tissues and converted to meat, milk and other animal products. For this reason, the energy source is often evaluated as digestible energy or metabolisable energy (ME, MJ/kg dry matter, or simply M/D), i.e. the energy in the feed ingredient that is available to animal tissues to meet the animal's tissue requirements after the losses due to digestion and absorption have been taken into account. Similarly, protein availability is sometimes referred to as metabolisable protein but it is worth noting in this context that all higher animal cells and tissues actually need amino acids (or small peptides) rather than non-protein N (NPN) or protein itself.

Sheep are ruminants with a specialised forestomach consisting of four compartments – rumen, reticulum, omasum and abomasum. The first three compartments are often referred to simply as 'the rumen', together hold 4-7 kg of watery contents consisting of the ingested feed and myriads of microorganisms. This feed is subject to continuous degradation, under oxygen-free (anaerobic) conditions, by a myriad of microbes including bacteria, protozoa and fungi. These microbes are able to

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grow rapidly in highly suitable conditions that are maintained by the host animal (well-mixed contents, buffered pH of 5-7, a regular supply of growth requirements and removal of digestion end-products, constant temperature). However, because the rumen conditions maintained by the host animal are anaerobic, the biochemical degradation possibilities are markedly restricted and so the microbes capture only a small fraction of the feed energy for their own use. In fact, they 'excrete' most of the feed energy in the form of volatile fatty acids (VFA). VFA are absorbed through the rumen wall, pass into the bloodstream of the host and then are subject to aerobic biochemical processes (oxidation). The microbial cell components (protein, lipids, storage carbohydrates, nucleic acids etc) pass out of the rumen and are digested to simpler materials that are absorbed from the intestines. These components provide amino acids and energy for the host. The overall effect of the rumen and its microbes is to modify the protein and energy containing materials from the diet before they are further degraded by the host animal's digestive processes.

Two key abilities are provided to ruminants by the rumen microbes:

- An ability, not present in non-ruminant animals, to degrade cellulose and other fibrous materials, thereby releasing individual glucose molecules as an energy source for the rumen microbes and, indirectly, for the animal
- An ability to synthesise the 20 amino acids (including the 9 essential amino acids) needed by all animal tissues from non-protein nitrogen (NPN) sources such as urea.

Most of the feed energy degraded by rumen microbes leaves the rumen and becomes available to the animal as VFA and microbial cells (but a small fraction is also lost as methane gas and as heat generated by the microbes). Of course there is also a considerable amount of energy in the undigested feed materials that pass from the rumen to the intestines. A small fraction of this energy is digested and removed from the small intestine, and a little more is degraded by the action of microbes in the large intestine and absorbed as VFA, but most is excreted as faecal materials.

Protein degraded in the rumen (often referred to as rumen degradable protein) is hydrolysed to peptides, amino acids and eventually ammonia by the microbial enzymes; the microbes can, however, also use all of these nitrogenous products to rebuild protein for their own purposes; the feed protein that is not degraded in the rumen passes intact to the intestines where it may still be degraded by the host animal's digestive enzymes and is referred to as bypass or escape protein. These microbial and escape protein sources are degraded to peptides and amino acids by the host's enzymes in the abomasum and small intestine and are efficiently absorbed; microbial and 'escape' protein are the source of amino acids in the body of the animal.

In effect, the activities of the rumen microbial population have a major role in determining how much energy and nutrients are available to the tissues of the host sheep. So when we consider what to feed the sheep, we must also consider the nutritional needs of a 'healthy' microbial population in the rumen, i.e. feeding the sheep well is dependent on feeding the microbes well. Microbial cells requirements are generally similar to those of all living cells; an adequate supply of both energy and nitrogen in an appropriate ratio (around 9 gN/MJ of ME) is particularly important, but essential minerals and some vitamins must also be provided in the animal's diet.

19.2 Energy and nutrients

All cells in the body require energy and a variety of other nutrients in optimal ratios, in the first instance to stay alive (maintenance), and then to grow (increase in mass, production). At any time there is one nutrient that is 'most limiting nutrient', and thus all other nutrients are in excess of requirements. When more of the most limiting nutrient is supplied, another nutrient may then become the most limiting one.

Energy requirements

Every cell in sheep tissues requires energy supplying nutrients to stay alive. Additional energy is required to enable each cell to develop and grow. Cells in tissues and organs such as the brain, kidney, heart and lungs need energy to keep the whole animal alive and functioning, even if it is not growing, e.g. energy to pump blood and air into the lungs and for other muscular movements. Additional energy is required to allow a lamb or sheep to increase its muscle mass (growth of meat), or to support pregnancy and lactation.

For convenience we often talk about energy requirements for maintenance (animal staying alive with no net gain or loss of tissue energy stores), and for production (energy deposited in growing tissues or in products such as milk and wool). When considering sheep in production systems, assessment of energy

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requirements for maintenance should include, in addition to the energy needed to maintain tissues, the requirements for walking, moving around, to combat extremes of climate, and to mount immunity to disease. It is also necessary to recognise that ME is used with higher efficiencies for maintenance than for production (growth, lactation, growth of conceptus etc) and efficiency is also higher when the diet is provided as milk or solids, or it contains high (rather than low) digestibility materials.

The Australian Feeding Standards (SCA, 1990) use a general equation for predicting energy requirements of sheep for maintenance (MEm) and production. This equation recognises that MEm increases as feed intake increases, and takes account of gender and age of the animal, requirements for grazing and combating climatic extremes.

Thus, if production is known,

$$ME_m = K.S.M\ (0.28W^{0.75}\exp(-0.03A))/k_m + 0.1ME_p + ME_{graze} + E_{cold}$$

Whereas if intake is known,

$$ME_m = K.S.M\ (0.26W^{0.75}\exp(-0.03A))/k_m + 0.09MEI + ME_{graze} + E_{cold}$$

where

K=1.0 for sheep, S = 1.0 for females or castrates and 1.15 for rams

M is a factor that depends on the proportion of dietary energy obtained from milk (estimated as [1+(0.260.015a) where a is week of life and weaning at 17 weeks of age is assumed to occur when M=1.0),

W=live weight (kg)

A=age (years) with a maximum value of 6.0 when [exp(0.03A)] =0.84

K_m is the efficiency of use of ME for maintenance (0.85 for milk diets and 0.02ME content of the diet (MJ/kg DM for other diets)

MEI is total ME intake (MJ/d)

ME_p is energy (MJ) used directly for production

ME_{graze} is additional energy (MJ) incurred in walking and gathering feed

E_{cold} is energy expenditure associated with cold stress.

The equation implies that a 50 kg Merino wether will require 5-6 MJ of ME to maintain live weight. This requirement will increase by about 15% if the animal walks 6 km per day on flat ground, and by about 20 % if it walks the same distance in hilly country. Animals in a feedlot need to spend less energy on 'activity' maintenance and so can partition more to tissue accretion and so can grow faster.

Effects of climatic extremes depend on the length of wool on the sheep and the opportunities it has to shelter from wind and rain. A 50 kg wether with only 5 mm of wool standing in wet, windy conditions at 10°C would need to generate additional heat to maintain its core temperature.

Growth of lambs and production of milk by ewes involves the production of various macromolecules, especially lipids and proteins. These materials contain chemical energy, i.e. lipid 39 MJ/kg, protein 24 MJ/kg and carbohydrate 18 MJ/kg. For optimal growth rates in lambs or for acceptable milk production in ewes, the total ME requirement may be 2-3 times that for maintenance.

N.B.: It is not necessary to remember the equations for estimating ME requirements, but the factors that affect requirements need to be well understood.

Energy supply

All energy found in forages or cereal grains was originally solar energy trapped by photosynthesis in plant cellular materials such as sugars, starches and in structural materials such as cellulose, hemi-cellulose and pectin. These materials represent the organic component of animal feeds. The organic materials contain all of the energy present. This energy is the gross energy of the feed and it is the amount of energy that will be released as heat if the material is fully oxidised to carbon dioxide and water by burning it in an enclosed oven. The small amount of remaining inorganic material, or ash, consists of minerals such as Na, K, silica etc. It is no accident that animals breathe out carbon dioxide and water vapour, as the process of biochemical oxidation in aerobic cells also releases energy, but differs from simple combustion in that some of the energy released is trapped in chemical forms (e.g. ATP) that can be themselves degraded to supply the energy for synthesis of new protein in muscle cells (meat) and for fat deposition. Combustion or biochemical oxidation of substrates such as glucose or ethanol in animal tissues yields exactly the same amount of energy – although the form of energy differs, e.g. heat versus chemical energy.

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You should already be familiar with energy classifications, i.e. gross energy, digestible energy, metabolisable energy (ME) and net energy. Of the total or gross energy determining by combusting forages (usually about 18 MJ per kg dry matter [DM]), a fraction is digested and removed from thegut, with the remainder being lost mainly in faeces; however, smaller fractions are lost in urine and eructated methane gas from the rumen. We refer to the energy not so removed as the ME concentration of the feed. ME the energy that is available to the animal's tissues to meet requirements for maintenance and production.

ME concentration of the diet is quite difficult to determine in practice and is often predicted from DE, e.g. ME = 0.81 x DE. The digestibility of the dry matter (DM) of forage materials varies widely in sheep - from about 80% in young rye grass or clover to as low as 40% in hay and straw made from mature pasture or cereal stubbles. Thus for forages with a gross energy value of 18 MJ/kg DM (M/D = 18), the DE values for rye grass and for straw would be about 14.4 and 7.2 MJ/kg DM. In general, ME values are about 81% of the DE values, corresponding to M/D 11.4 for fresh rye grass and M/D 5.8 for stubbles and straws. In general, ME concentrations of forages decline as the materials mature when soluble sugars and starches are replaced by cellulose; although cellulose itself is digestible, it is often encased in indigestible lignin and sometimes silica in the cell walls that slow its rate of digestion by rumen microbes and lower the overall digestibility of the material in which it is found. Tropical forages at the same stage of maturity usually have lower ME values than temperate forages.

19.3 Protein requirements

As well as needing continuous supplies of energy supplying substrates, cells also have on-going requirements for amino acids to make their proteins. All cells continuously synthesise new proteins from amino acids, and then degrade some of them when they are damaged or no longer required. This synthesis-degradation process is referred to as 'protein turnover'. The difference between the rates of synthesis and degradation determines the amount of protein deposited (muscle protein, meat). It will be obvious that, at an absolute minimum, 1 g of amino acids must be supplied to deposit 1 g protein. Often, however, in growing animals, the rate of protein accretion is only 20% of the rate of turnover. Most of the amino acids released in the degradation process are recovered and re-used, but some not, especially for synthesis of proteins that have quite different amino acid compositions. Protein synthesis and degradation rates are subject to separate control systems that can differ between genotypes. Both can also be manipulated by the so-called growth promoters. These can increase protein deposition by either increasing protein synthesis rate or decreasing degradation rate or possibly both. In any event, the quantity of amino acids needed always exceeds the quantity deposited in meat and milk.

Because some of the amino acids turned over in cells are not recaptured, there is always a small requirement for amino acids even when animals are not growing or producing. This is the protein requirement for maintenance and is the minimum amount required to enable the animal to survive. Additional supplies of protein and amino acids are required for production, i.e. to enable net deposition to occur, for example, to support deposition of muscle protein (meat production) and the amounts required depend on the digestibility of the protein source and its quality (amino acid composition).

Protein and energy requirements are inter-dependent. Growing cells require both protein and energy for maintenance purposes, and to deposit both fat (energy) and protein in genetically determined ratios. Requirements for tissues therefore need to be thought of in terms of a desirable protein: energy ratio in the absorbed nutrients. The optimal ratio will vary for particular forms and levels of animal production.

Because tissue deposition involves a net gain in protein in the body of the animal, additional building units must come from outside the animal, i.e. from amino acids absorbed from the intestines. However, the intestinal requirement is always greater than the actual amount of protein deposited. This is because the protein deposited in cells is synthesised from amino acids derived from intracellular compartments where the amino acid ratios are not the same as those of digested dietary or microbial protein. Because of the mis-match, some amino acids in the bloodstream that are in excess of cellular requirements are degraded and the amino-N released is synthesised into urea in the liver which is then excreted in urine. More amino acids must therefore be absorbed from the gut than are actually deposited in tissue protein and some N (crude protein) is wasted. So-called 'high quality' proteins are well matched to the 'target' proteins being synthesised in the tissues and used efficiently. On the other hand, low-quality proteins are poorly matched and used less efficiently and, accordingly, larger amounts of urea (the end-product of excess amino acids) are produced per unit of protein absorbed. Clearly, the true protein or amino acid requirements at the tissue level, and therefore at the intestinal level, are dependent on the quality of protein supplied to the intestines. In the case of ruminants, most of the amino acids delivered to the intestines are in the form of microbial protein whose amino acid composition is a fairly good match for

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'target' proteins (except wool). Thus, ruminants are largely independent of dietary protein. However, if appreciable amounts of escape protein are included in the diet, the ratios of amino acids in digested and absorbed proteins can be altered somewhat – and, depending on the amino acid composition of the escape protein source, possibly improved.

Wool protein deposition is a special case. Microbial proteins and most escape proteins have a rather different amino acid composition from wool protein (clean wool is almost pure protein). The latter is relatively high in cysteine - a sulphur-containing amino acids derived from the essential amino acid, methionine - and so most amino acids in the blood supplying wool follicles are considerably in excess of requirements for wool production. Circulating amino acids are therefore used with less than 20% efficiency for wool production.

Protein supply

Protein, or more specifically the essential amino acids, are provided by digestion of rumen microbial protein and 'escape' or 'bypass' proteins that pass from the rumen into the lower gut as discussed above.

Muscle is the largest single protein mass in the body (about 50% of the total protein). Muscle cells of both non-ruminant animals (e.g. pigs, poultry) and ruminants (sheep, cattle) must be supplied via the blood with 20 different amino acids to be able to synthesise the thousands of different proteins that are their enzymes and structural components. These amino acids include the so-called essential amino acids like methionine and lysine that their tissues cannot themselves synthesise. Non-ruminants must have digestible true protein in their diet to obtain the essential amino acids. Ruminants including sheep, on the other hand, can manage quite well even if there is no true protein or amino acids in their diet, because all 20 amino acids, including the essential amino acids, can be synthesised from sources of non-protein N (NPN) such as urea by the microbes in the rumen. The microbial proteins formed from these amino acids can be digested in the intestines and the resulting amino acids absorbed into the bloodstream. Thus ruminants can be supplied with only NPN sources such as sulphate of ammonia or urea and can survive and even grow on such diets. i.e. diets that contain no true protein. Non-ruminants, including people, cannot survive for long on such diets.

All animals produce urea as an end-product of tissue protein and amino acid metabolism. Much of this urea travels to the kidney and is excreted in the urine. However, some is also secreted into the gut, via the saliva and other secretions and also by diffusion from the bloodstream, where it is quickly degraded to urea by in a reaction catalysed by microbial urease. In the rumen, this reaction gives rise to ammonia-nitrogen which can be re-used by microbes to synthesise microbial protein that can again undergo digestion and absorption from the intestines. By this means the ruminant animal can re-use some nitrogen and thus survive and grow on diets that contain less dietary nitrogen (crude protein) than that needed by non-ruminants. This recycling of N via urea is sometimes referred as 'urea recycling' or a 'protein regeneration cycle'. The ability of rumen microbes to produce true protein from NPN sources also enables ruminants to be supplemented with urea via their diet or in their drinking water and generate their protein needs from these NPN sources.

19.4 Mineral requirements

Animal production can be limited by a deficiency of any of the essential components of a balanced diet – i.e. ME, amino acids, minerals, vitamins or water. Dietary ME or nitrogen supply are the most common limiting factors, but at times certain macro-or micro-minerals can also limit production. A number of the minerals are essential and therefore must be provided in adequate amounts in the diet. Periods of rapid growth, pregnancy and lactation increase the demand for essential minerals.

Mineral deficiencies are more likely in some situations than in others, but can be difficult to diagnose. Generally adult ewes grazing on pasture have sufficient stores of minerals to provide for their own needs and those of their foetus, but deficiencies can occur in growing lambs during times of seasonal deficiency. Trace element deficiencies (e.g. Se, Co and Cu) are reasonably common in new-born lambs, suckers and recently weaned lambs in some parts of Australia. Oral drenches, injectable products and intra-ruminal release devices can be used in these situations. Fertilisers containing minerals such as Se and Cu can also be applied to pastures to increase the levels of these minerals in the plant materials. There is a well-known interaction between Cu, Mo and S that can generate Cu deficiency in grazing sheep by reducing Cu absorption from the gut. On the other hand, sheep have a narrow window of tolerance for Cu; concentrations of dietary Cu that are greater than about 8 µg/kg DM can become toxic, especially if Mo concentrations in the diet are low, i.e. below 1 µg/kg DM. For this reason, lambs should never have access to pig or poultry feeds.

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Sheep given concentrate diets need special consideration. They can deplete their reserves of minerals within a month if given a predominantly grain diet. Cereal grains are low in Ca and high in P and need to be supplemented with Ca (1 % finely ground limestone) to lift the Ca to P ratio in the diet to about 2:1. Imbalance in Ca to P ratio can lead to low feed intakes, poor growth and also brittle bones; it can also lead to formation of urinary calculi that can block the ureter and lead to the potentially fatal condition called 'water belly'. Lambs held in feedlots should be periodically given a mineral mix to ensure there are adequate supplies of other essential minerals.

19.5 Vitamin requirements

Vitamins are essential nutrients. Sheep obtain their vitamins from green forage and microbial synthesis in the gut. Sheep that have recently had access to green feed will seldom exhibit vitamin deficiencies, but reserves may be depleted over several months if they have access only to dry feeds. Periods of rapid growth, pregnancy and lactation increase the requirements for vitamins.

Vitamins A, D, E and K are the fat soluble vitamins; vitamins A, E and K are found in green forage. Vitamin A is stored in the liver in sufficient amounts to meet the requirements of a sheep for about 3 months and the active form of vitamin D is produced in the skin if animals are exposed to sunlight. Vitamin D is actually a steroid hormone that has an important role in regulating body levels of Ca and P, and in mineralization of bone. Vitamin D3, also known as cholecalciferol is generated in the skin of animals when light energy is absorbed by a precursor molecule 7dehydrocholesterol. Being strictly correct, it is not, as often stated by students in exams, 'made from sunlight'! Vitamin E and Se, both of which function as anti-oxidants, can partially replace each other but deficiency can lead to 'white muscle disease'.

The B vitamin complex and vitamin C are the water soluble vitamins; microbes in the gut normally synthesise enough B vitamins to meet requirements, and vitamin C can be synthesised by the sheep itself. Cobalt is a component of Vitamin B12 and this vitamin may not be synthesised in adequate amounts by the gut microbes if the animal is Co deficient. Thiamine (Vitamin B2) deficiency is sometimes caused by the activity in the rumen of thiaminase from ingested plants or produced by microbial populations growing under conditions of slow turnover in the rumen caused by high grain, low-fibre diets.

19.6 Practical feeding management

Increasing lambing percentage is one of the most effective ways of increasing profit from sheep properties and good nutrition of ewes and rams is central to achieving this goal.

Feeding ewes - Pre-mating and mating

Live weight and body condition (fatness) affect ovulation rates of ewes at mating. First-time breeders (maiden ewes) may require special supplementation in their second year if pasture conditions are sub-optimal. Older ewes must be prepared for re-breeding in the period between weaning and mating. In general, managers should aim to increase the ewe's live weight and have them in forward-store condition (fat score 3) at the time of next mating (Adalsteinsson, 1979). Lambing percentage is affected by pre-mating condition score and live weight two months before mating, and live weight change from 8 to 2 weeks before mating.

At the time of mating, nutritional enhancement or 'flushing' is a widely used to improve ovulation rates. Short-term (4-6 day) increases in energy and nutrient supply that are sufficient to promote weight gain and fat deposition, while ewes are in the luteal phase, will increase ovulation and conception rates, especially when earlier pasture nutrition has been poor (see Rowe and Atkins 2004).

Ewes can be 'flushed' by moving them to good quality pasture or by offering them supplements such as grains or oil-seed meals at 0.0.1-0.3 kg/head per day. (High levels of ruminally degradable protein or urea supplements are not recommended as higher blood urea concentrations are thought to be associated with detrimental effects on conception rate.) For practical reasons, improved nutritional conditions will need to be maintained throughout the period while the rams are active. Ewes that are in poor body condition during mating will tend to be less responsive to flushing, as will ewes that are too fat.

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Feeding ewes during pregnancy

From joining to about 6 weeks before lambing (the 'transition' period), nutrition is not critical provided the ewe maintains weight. Underfeeding in mid-pregnancy can restrict udder development and reduce subsequent milk production (Geenty, 1998). During the transition period, however, nutrition should be improved to maintain live weight of the maternal tissues (total ewe and conceptus weight increasing). At this stage, feed intake is likely to be restricted by a reduced rumen volume caused by foetuses and conceptus occupying the body cavity and so more 'energydense' diets may be needed. Severe underfeeding in late pregnancy can lead to low lamb birth weights and low lamb survivability. Overfeeding, on the other hand, can lead to birth difficulties and over-fat ewes are also more prone to pregnancy toxaemia after birth of their lambs. Supplementation with concentrates and particularly protein concentrates in late pregnancy may allow the ewe to produce more colostrum and improve lamb survival rates (Geenty, 1998).

In dairy cow production, transition management focuses on mineral nutrition and dietary cation-anion balance (DCAB) which is thought to be important in promoting early bone calcium mobilisation and preventing hypocalcaemia (milk fever) during early lactation. This problem, however, seems to be less important in sheep.

More detailed recommendations concerning feeding of ewes during pregnancy are available and take account of the ewe's feed requirements for maintenance, and additional requirements as defined by stage of gestation, condition score, change in live weight of the ewe and the number of foetuses she is carrying (see Hegarty, 2003).

Feeding ewes during lactation

Nutrition of the ewe during lactation has a major effect on milk production and growth of the lamb, as well as affecting her body condition and live weight as lactation proceeds. With the onset of lactation, feed intake increases substantially but, nevertheless, considerable amounts of body reserves may be used to support the drain in nutrients imposed by milk production, especially if energy concentration in the diet is relatively low. Growth of the lamb seems to be largely limited by milk protein supply rather than milk energy content; it is relatively easy to increase the fat content of milk by dietary manipulation, but much harder to increase milk protein concentration (Hegarty, 2003). Typical values for the composition of ewe's milk (g/kg liquid milk) are: fat 71, protein 57, lactose 48, ash 9 and solids-not-fat 115 (Ashton *et al.* 1964). At the same level of nutrition, ewes with twin lambs generally produce about 40% more milk than those with singles (Treacher, 1983)

GrazFeed software, based on the Australian feeding standards (SCA, 1990) can predict ewe and lamb performance in response to different diets and rations for ewes, while taking account of the number of suckling lambs (single or twins) and their age and live weight.

Feeding lambs

After weaning, lambs may be sold as 'suckers', kept as flock replacements or grown further on pasture on in feedlots to meet the fat lamb market. (Previous ewe flock management will have affected the size and health of lambs at weaning -selection of lambing time, duration of lambing period, ewe nutrition before and during lactation, parasitism of ewes and lambs before weaning.) In Australia there is a market for Merino and crossbred lambs.

Nutrition, management and pathogenic organisms are involved in a number of clinical syndromes in all sheep. The array of syndromes is particularly evident in weaner sheep and is often referred to as 'weaner ill-thrift'.

Nutrition has a particularly important role in preventing 'ill-thrift'. From birth to weaning, usually at 34 months of age, lamb growth is determined by their milk intake. At 20 kg live weight, Merino weaners have only about 1 kg of fat. Dietary deficiencies in lambs weighing less than 20 kg will result in the mobilisation of body protein stores with consequent deleterious effects including increased susceptibility to disease, loss of resilience, weakness, and even death. However, fat reserves increase rapidly with increased live weight above 20 kg. The weight and health of lambs at weaning will have 'knock-on' effects on performance of weaners in the post-weaning phase, with weaning above 20 kg giving considerable advantages.

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Pasture-fed lambs

Weaner lambs over 10 weeks of age should be capable of ingesting at least as much dietary organic matter per unit of metabolic live weight (W0.75) as mature sheep, i.e. about 3-4% live weight. However, pasture-fed lambs normally grow less quickly than grain-fed lambs. Because of their high energy and protein requirements for growth, pasture-fed weaners are often the first group on the farm to require supplementation at the end of the pasture growing season when plants flower and senesce and their digestibility and ME concentration fall markedly. Also, if the dietary supply of trace elements is low, young sheep are often the first, or only, group of sheep on the farm to exhibit signs of deficiency because of their high requirements for growth and limited opportunities to build up reserves. Even for lambs on fresh green pasture, there appear to be other factors that constrain intake and production to levels below those possible with grain-based diets.

Weaner ill-thrift can also result from anti-nutritional factors in pasture materials. For example, most perennial ryegrass plants found in Australian pastures contain the endophyte Neotyphodium lolii, located within the plant and not visible to the naked eye. Neurotoxins produced by this endophyte in response to signals from the plant affect the animal's nervous system and produce the condition called ‘Rye grass staggers’. Weaners have a stiff gait and lose control of their direction of movement so are unable to graze and may not be able to get to water. In severe cases animals become uncoordinated and may even collapse in a tetanic spasm. However, they usually recover when left alone.

Despite the disadvantages of raising grass-fed lamb, advocates for this strategy will point to health benefits to be gained from eating their meat and milk. These products contains more conjugated lineolic acid (CLA), vitamin E, omega-3 fatty acids, beta-carotene, and vitamin A than the meat and milk from grain-fed animals. CLA and omega-3 fatty acids are ‘good fats’ with anti-cancer, anti-diabetes, and anti-fat properties (Scollan and Huws - Recent Advances, 2005).

Feedlotting

When pasture conditions are unsuitable for growing lambs, they are often finished for market in feedlots. In the feedlot, the lambs are totally dependent on the operator for their feeding and care. Normally lambs are between 4 and 9 months of age at the start of feeding and weigh at least 35 kg. First-cross lambs can be expected to ingest 1.4-1.8 kg/d and grow at 250-350 g/d whereas Merino lambs will eat less, 1.1-1.6 kg/d, and grow at 150-250 g/d. As a guide, to grow from 35 to 45 kg, crossbred lambs will take about 5 weeks and will eat about 58 kg of feed, whereas Merinos will take about 7 weeks and will eat about 66 kg. However, food conversion efficiencies of 4 kg feed/ kg gain are possible with some genotypes.

As with all sheep nutrition, when formulating the feedlot diet, ME, protein, minerals, vitamins and water all need to be carefully considered. ME is mainly supplied by the grain component of the diet so that the energy concentration is 11-12 MJ/kg. Grains have a high starch concentration and should be introduced slowly as the roughage content is reduced to reduce the risk of acidosis. Some grains pose a greater risk of acidosis than others, with oats and sorghum for example being safer than wheat and barley. Processing of grains increases the risk of acidosis, but is not necessary for lambs and so it is not recommended. When choosing which grain to feed, it is helpful to consider the costs per unit of ME, i.e. $/MJ. It is common practice to include 15-35% of hay or silage in the diet to increase salivary flow rate and pH buffering in the rumen, and diets are sometimes pelleted to force the lambs to eat the intended grain:roughage ratio. Different roughage sources vary in their ability to promote healthy rumen function – e.g. barley and oaten straw are considered to have more suitable fibre properties than wheat or sorghum straws. Straw is one of the best and least expensive forms of roughage because it is very high in effective fibre, i.e. is likely to contain more than 70 % effective fibre whereas a high-quality hay may contain less than 50 % effective fibre. Thus less straw than hay needs to be included in the diet to achieve the same effective fibre effect. Inclusion of straw rather than hay helps to keep the energy content of the diet high as well as reducing mixing costs and improving feed intake.

Rumen degradable protein

Lambs require a diet of about 15% crude protein (14-18%) to supply sufficient ammonia for the growth of rumen microbes; the requirements depends on their induction weight and their genetic potential for growth. Younger lambs, and lambs selected for higher growth rates and improved feed efficiency have higher requirements for amino acids. Generally speaking, lambs under six weeks of age or 20 kg live weight are less able to utilize protein derived from urea. Heavier lambs can utilise up to 2% urea in the diet as a NPN source from which rumen microbes can synthesise their amino acids. The N to S ratio in the diet should be between 10:1 and 13.5:1 to provide N and S for the microbial synthesis of S-

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containing amino acids. In its granular form, urea can readily separate out of whole grain mixes and accumulate in feeders at levels that could cause losses due to ammonia toxicity.

Escape protein

McGregor and McLaughlin (1980).evaluated diets containing 9-21 % CP and either 12.4 or 14.4 MJ DE/kg DM for growing weaner wethers. They concluded diets for weaner wethers should contain 18 % CP. Their diets contained barley oats and linseed meal. Some true protein will be provided by most feed ingredients. Providing a feedlot diet is predominantly grain and is balanced for ME and crude protein, there are unlikely to be substantial benefits from including additional escape protein sources in the diet. If, however, S or some other mineral is limiting, or the diet is deficient in other essential nutrients, a non-specific benefit might be obtained when high-protein meals are included.

Minerals and vitamins

Most feed ingredients provide some minerals and vitamins. Most grain-based diets have a low Ca:P ratio and require supplementation with about 1% ground limestone as discussed earlier. For lupin based diets, gypsum can be used to supply additional S. NaCl is included in grain based diets at 0.5-1.0% if it is not present in the water supply. Generally trace mineral supplements should not be needed and operators should always be aware of potential toxicity from Cu (see earlier discussion). Sodium carbonate is sometimes included in feedlot diets as a buffer maintain a higher rumen pH and to reduce the risk of acidosis, but large amounts are needed to have a significant buffering effect. Bentonite, with its ability to bind compounds may, have beneficial effects such as minimising the effects of anti-nutritional factors (e.g. endophyte neuro-toxins). Lambs that have not had access to green feed for 2 months may need supplements of Vitamin A or Vitamin E.

Water

Lambs require unlimited access to cool clean water (up 4 l/d depending on conditions). Troughs should be situated well way from feeders to minimise contamination of the drinking water as poor water quality can reduce feed intake. Urinary calculi (‘water belly’) is often linked to low water intakes in feedlot situations.

Feeders

Current industry practices indicate that lambs require 1.5 cm of trough space per head in a self- feeding situation, and that the trough should be a minimum of 40 cm above the ground to prevent faecal contamination of feed. The feeder design should prevent lambs from climbing into the toughs. Similarly, in bunk feedlot situations, 5-10 cm of trough space per lamb is generally used as the standard throughout the industry.

Feedlot adaptation

To give the rumen microbes time to adapt to the high starch diets and minimise the likelihood of acidosis, lambs should be introduced to grain over a 2-3-week period. A starter diet (about 35% grain) can be given over the first 10 days, and an intermediate diet from days 11 to 20. After Day 21, a finisher diet (75-85% grain) can be used.

Ideally, diets should be formulated on the basis of actual analyses of the available raw materials. A wheat-based diet will require a higher straw fraction than one based on oats and barley that both have higher fibre contents than wheat.

Sample diets

Some examples of feedlot diets given by NSW Department of Primary Industries (Bell *et al.* 2003) are reproduced below.

Table 19.1: Diet 1. Diet based on wheat and lucerne hay (M/D 11.7, CP% 15.5) (Bell *et al.* 2003).

	ME content (M/D, MJ/kg DM)	Crude protein content (%)
70% wheat (13M/D:12% CP)	9.1	8.4
29% lucerne hay (9 M/D:16% CP)	2.6	4.6
1% urea (0 M/D:250% CP)	0	2.5
1.5% limestone		
1.5% NaCl		

Diet 1 should be capable of achieving growth rates of about 270g a day but this will vary with age and weight. Protein should be adequate except for light lambs.

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Table 19.2: Diet 2 Diet based on wheat, clover hay and lupin (M/D 12.3, CP% 15.1) (Bell *et al.* 2003).

	ME content (M/D, MJ/kg DM)	Crude protein content (%)
65% wheat (13 M/D:12% CP)	8.5	7.8
20% clover hay (9 M/D:14% CP)	1.8	2.8
15% lupin (13 M/D:30% CP)	2.0	4.5
1.5% limestone		
1.5% NaCl		

Diet 2 should be capable of achieving growth rates of about 290g day (see Table 2) but this will vary with age and weight. The ration is probably protein deficient for light lambs.

Table 19.3: Diet 3. Diet based on barley, lucerne hay, lupin and wheat straw (M/D 11.7, CP% 16.2) (Bell *et al.* 2003).

	ME content (M/D, MJ/kg DM)	Crude protein content (%)
65% barley (13 M/D:12% CP)	8.5	7.8
14% wheat straw (5 M/D:5$ CP)	0.7	0.6
15% lupin (13 M/D:30% CP)	2.0	4.5
5% lucerne hay (10 M/D:16% CP)	0.5	0.8
1% urea (0 M/D:250% CP)	-	2.5
1.5% limestone		
1.5% NaCl		

Diet 3 should be capable of achieving growth rates of about 270g a day but this will vary with age and weight. Protein should be adequate for all lambs.

With careful management, it is possible adapt lambs in 10 days to their final diet that can contain less than 10% straw. Barley and oaten straw are considered to have more suitable fibre properties than wheat or sorghum straws. Lucerne hay and molasses are sometimes added to improve the attractiveness of the diet; mouldy ingredients can greatly reduce attractiveness and intake and production.

Feeding cast-for-age sheep

Cast-for-age (CFA) sheep can be grain-fed to enable critical carcase grades to be met. An extensive study by (Bowen *et al.* 2006) and (Jordan *et al.* 2004) has shown that CFA sheep can be successfully fed on diets similar to those listed above.

Readings

There are no readings available on web learning management systems. Students are advised to access and read articles of interest from the reference list.

References

Adalsteinsson, S., 1979. 'The independent effects of liveweight and body condition on fecundity and productivity of Icelandic ewes.' Animal Production, vol. 28, pp. 13-23.

Ashton, W.M., Owen, J.B. and Ingelton, J.W., 1964. 'A study of Clun Forest ewe's milk.' Journal of Agricultural Science, Cambridge, vol. 53, pp. 85-90.

Bell, A.K., Shands, C.G., Hegarty, R.S. and Duddy G., 2003. Feedlotting lambs, Agnote DAI/42* 2nd Edition, NSW Agriculture, ISSN 1034-6848. http://www.animalethics.org.au/reader/sheep-grazing/dai42ed2.pdf?MIvalObj=16942&doctype=document&MItypeObj=application/pdf&name=/dai42ed2.pdf, retrieved July 20th, 2006.

Bowen, R.W., Jordan, D.J., Berretta, V., Savage, D.B., Pethick, D.W. and Rowe, J.B., 2006. 'Sorghum performance in sheep feedlot diets.' 5th Australian Sorghum Conference, Gold Coast, p.63, Australian Sorghum Conferences Association Inc.

Egan, J.K. and Doyle, P.T., 1982. The effect of stage of maturity in sheep upon intake and

Geenty, K.G., (ed) 1998. Improved Lamb Percentage. Wools of New Zealand, Palmerston North, ISBN 0-908768-75-3.

Hadjipanayiotou, M., 1995. 'Composition of ewe, goat and cow milk and of colostrum of ewes and goats.' Small Ruminant Research, vol. 18, (3), pp. 255-262.

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Hegarty, R.S., 2003. General nutritive requirements of sheep and goats. In: Encyclopaedia of Dairy Sciences, eds H. Roginski, J. Fuquay and P. Fox, Academic Press, Amsterdam.

Jordan, D.J., Mills, A., Newell, G., Pepper, P.M. and Rowe, J.B., 2004. 'Feedlotting castle-for-age Merino sheep to increase their value.' Animal Production in Australia, vol. 25, p. 269.

McGregor, B.A. and McLaughlin, J.W., 1980. The influence of dietary protein and energy concentration on the growth of Merino weaner sheep Australian Journal of Experimental Agriculture and Animal Husbandry, vol. 20, (104) pp. 308-315.

Rowe, J.B., 2003. 'Nutritional management of the Australian sheep flock.' Recent Advances in Animal Nutrition in Australia, vol. 14, pp. 23-31.

Rowe, J.B. and Atkins, K.D., 2004. Increasing productivity in the Australian sheep flock. ABARE Conference, Canberra.

SCA 1990. Feeding Standards for Australian Livestock: Ruminants. Standing Committee on Agriculture (CSIRO, Melbourne) p. 266.

Scollan, N.D. and Huws, S.A., 2005. 'Enrichment of ruminant products with nutritionally beneficial fatty acids.' Recent Advances in Animal Nutrition in Australia, vol 15 pp 21-31.

Treacher, T.T., 1983. Nutrient requirements for lactation in the ewe. In W. Haresign, ed. Butterworths, London, pp.133-153.

Vinoles, C, Forsberg, M, Martin, G B, Cajarville, C, Repetto, J and Meikle A (2005). Short-term nutritional supplementation of ewes in low body condition affects follicle development due to an increase in glucose and metabolic hormones Reproduction 129(3): 299–309.

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