Animal nutrition, production and reproduction

Nutritional needs are for energy, nitrogen (protein), essential minerals and vitamins which are met by the intake of various combinations of pastures, forage crops, conserved forages (hay and silage) and concentrates (grains and processed meals).

The feeding objective is to supply the level and balance of nutrients required to meet the production, reproductive and product quality targets of the livestock enterprise as efficiently and economically as possible.

Principles

Feed intake, or the diet selected (amount and quality), is the key nutritional variable driving animal production and reproduction.

Feed ingested by ruminants must provide all the nutrients essential for fermentative digestion in the rumen, as well as providing the undegraded proteins and starch which pass through (by-pass) the rumen to the small intestine (Figure 3.1).

Figure 3.1. Digestion of a basic diet supplemented with by-pass nutrients (Preston 1984).

The intake of fermentable material in forage is enhanced by an increase, within limits, of the amount of escape or by-pass protein in the diet, and is decreased when low quality forage (roughage) dominates the diet.

The efficiency of feed conversion increases, again within limits, as the amount of by-pass starch increases.

Nutrients are required for ‘maintenance’ functions (the factory overheads) and for ‘production’ (the commodities produced).

Energy intake required for resting or maintenance functions is proportional to metabolic body weight, which is a function of liveweight (LW) and expressed as LW$^{0.75}$; grazing animals on average may require 30 percent more maintenance energy for walking than stall-fed animals (Kleiber 1961).

Energy, protein and mineral requirements for production are additional to those required for maintenance; production is only possible after maintenance requirements are met.

Type, breed or genotype, class, size, physiological state (eg. growing, gestating or lactating) and age of the animal all influence nutritional requirements for ‘maintenance’ and ‘production’ (Figure 3.2).
A process approach to production from animals at pasture

The process is illustrated by a simple model (Figure 3.3). The model incorporates the primary variables of environment, plant growth, the amount and quality of pasture on offer, the diet selection process which determines the amount and quality of the diet, and the animal metabolic processes which determine the energy and nitrogen (N) balance of the animal and its production.

Figure 3.3. A model relating pasture growth, diet selection, animal metabolism and animal production. The square boxes represent state variables, and the others are rate variables.

Liveweight gain depends mainly on the interrelationship between energy and protein (amino acids) delivered to the body tissues from the rumen and the small intestine up to the genetic limit for protein synthesis; the limit is probably never reached for grazing animals.

Figure 3.2. Generalised relationships between maintenance energy needs and the liveweight, age and pregnancy status of the animal (Morley 1978).
Feed intake

In the paddock, many pasture, animal and climatic variables interact to modify the amount and quality of intake. Important ones are the:

- **total amount of forage on offer**, expressed as total kg dry matter (DM) per ha, or the forage allowance available, expressed as kg of DM or organic matter (OM) per animal or per unit of animal LW

- **feed quality** or total dry matter digestibility of the pasture, expressed in terms of the proportion of the total DM or OM that the animal can digest (% dry matter digestibility (DMD)) or % organic matter digestibility (OMD)

- **grazing time** (hours per day)

- **amount and quality of feed supplements**

- **harmful plant substances** which depress intake

- **animal liveweight, age and physiological state**.

Pasture on offer or forage allowance

The amount of forage available to each animal determines the ease with which the animal can obtain the highest quality and most digestible diet possible from the feed on offer. Intake is maximised when the forage allowance exceeds about 50 g of DM per kg LW per day (Figure 3.4). Under light stocking rate this equates to a green pasture yield above about 1000 and 2500 kg DM per ha for temperate and tropical pastures respectively.

Figure 3.4. Forage allowance and its effect on intake by calves, beef cattle and dairy cows (Ernst et al.1980).

Forage quality and digestibility

Digestibility is determined by the energy and protein content of the forage.

These are related to the ratio of plant cell components in the form of ‘cell contents’ (high energy and protein) and cell walls (fibre and silica). The less digestible cell wall component increases as plants age (Figures 3.5 and 3.6).

Figure 3.5. Changes in the chemical composition of grasses as they age (Osbourne 1980).

Figure 3.6. Digestibility of temperate and tropical grasses, and of grain and crop by-products in the tropics (McDowell 1985).
Tropical forage plants have overall higher crude fibre and silica contents than temperate species and therefore have lower digestibility. Mature grasses are generally less digestible than mature legumes, and differences between tropical and temperate legumes are less than those between tropical and temperate grasses (Figures 3.6 and 3.7).

Figure 3.7. Frequency distributions showing differences in digestibility between tropical (—) and temperate (—) grasses and legumes (Wilson and Minson 1980).

Intake of forage is highly correlated with the digestibility of the diet selected (Figure 3.8).

Figure 3.8. Relationship between intake of tropical forage and digestibility of the diet selected (Minson 1990).

Overall digestibility of green pasture in the paddock decreases as the amount of the green pasture on offer increases, although the digestibility of the diet increases due to the greater opportunity for diet selection (Figure 3.10).

Figure 3.9. Relation between mean voluntary daily intake (g per unit of metabolic weight) and dry matter digestibility for a wide range of tropical (—) and temperate (—) grasses (Minson 1980).

Figure 3.10. Digestibility of green pasture on offer and the diet of sheep in relation to the amount of available green pasture (Hamilton et al. 1973).

The lower digestibility of tropical compared with temperate forages results in lower rates of intakes by animals grazing tropical forages (Figure 3.9).

Precision in selecting a diet differs between animal types due to bite differences; for example, the ‘sweep of the tongue’ by cattle compared with ‘nibbling’ by sheep; some production benefits may be achieved by grazing cattle and sheep together as they select different, though overlapping, ranges in diet.
High moisture content of forage lowers intake (Figures 3.11), but energy and protein supplements enhance it. Legumes generally provide forage protein at higher levels than grasses (except when the grasses are young and leafy), and therefore generally improve intake.

Figure 3.11. Effect of dry matter content of sorghum silage on voluntary intake by lactating cows (---) and beef steers (-----) (Minson 1990).

Grazing time

Animals have to graze for longer periods to achieve daily feed intake requirements when the amount of forage on offer and intakes are low (Figures 3.12 and 3.13).

Figure 3.12. Relationship between grazing time from morning to afternoon milking and pasture yield on offer in winter in south-east Queensland (Cowan and O'Grady 1976).

Figure 3.13. Relationships between grazing time by sheep, rate of forage intake, and forage yield (Allden and Whittaker 1970).

Heat stress from daily maximum temperatures above 25°C decreases grazing time of dairy cattle between morning and afternoon milking, a constraint prevalent for a substantial period between 5-6 months of the year in tropical dairying regions of northern Australia (Figure 3.14).

Figure 3.14. Association between the proportion of daily grazing occurring between morning and afternoon milking and daily maximum temperature (Cowan et al. 1993).
Heat stress is also a factor for beef cattle and sheep grazing in the hot and arid inland regions. Besides the effect on grazing behaviour, extreme low and high temperatures can directly cause lamb death through exposure, especially in open grasslands.

**Harmful substances**

Some pasture plants and weeds may contain substances that suppress intake; these substances fall into three categories:

- inorganic compounds and minerals eg. nitrate, copper and selenium
- organic compounds eg. various tannins, alkaloids (mimosine), alicyclics (saponins) and glycosides
- fungal/microbial toxins (mycotoxins).

Hungry or stressed animals can die when gorging on a range of plant species that are either intrinsically toxic or are toxic at certain times under certain conditions.

**Feed supplements**

Energy, protein and mineral supplements in the form of silage, hay, licks, inorganic minerals, grain or meal concentrates may enhance or decrease (substitute for forage) forage intake, depending on the quality of the base diet (Figures 3.15 and 3.16).

Figure 3.15. Voluntary intake of signal grass with (—) and without (—) a protein supplement of 4 g/kg LW 0.75 soybean meal (Minson 1990).

Figure 3.16. Effect of concentrate supplement on intakes of high, medium and low quality forages (Braster 1983).

Total intake and digestible organic matter intake is normally enhanced by supplementation (Figure 3.16), at least until deficiencies of dietary components are overcome. Further increments in the level of supplementation beyond this point leads to an accelerating substitution of the base diet by the supplement (Figure 3.17).

Figure 3.17. Silage intake in relation to concentrate allowance (after Østergard 1980).
Animal production and production efficiency

The approximate nature of relationships between daily animal production and feed intake, feed quality and animal physiological status are summarised in Figure 3.18.

Figure 3.18. Generalised responses in daily liveweight gain, milk production and wool growth to some feed and animal physiological variables (Morley 1978).

Production is determined mainly by intake of digestible dry matter and crude protein provided minerals are not limiting and there are no harmful substances in the feed.

Production efficiency is related to animal age and the associated changes in the composition of weight gain, the level of production, the extent to which the diet is metabolised in the body (e.g. metabolisable energy (ME) component), rumen volatile fatty acid (VFA) pattern, and mineral interactions:

- production efficiency falls as the composition of weight gain is increasingly dominated by fat deposition as animals gain in body weight with age, and as the proportion of nutrient intake used for protein synthesis falls (Figure 3.19)
utilisation of energy in the diet for production becomes more efficient as the metabolisable energy status of the diet increases; it is also influenced by rumen VFA composition (Figures 3.20, 3.21 and 3.22).

Figure 3.20. Effect of maize grain (high ME) in a hay diet on the efficiency of metabolisable energy use for maintenance and fattening in cattle (Minson 1990).

Figure 3.21. Relationship between metabolisable energy intake and energy retention in sheep fed spring or autumn herbage (Corbett et al. 1966).

utilisation of protein in the diet for production becomes more efficient as the protein concentration of the diet increases and as the proportion of by-pass protein increases (Figure 3.23).

Figure 3.22. Relationship between the proportion of propionic acid in the rumen VFAs and the efficiency with which metabolisable energy consumed above maintenance is used for tissue synthesis or k (kJ%) (Preston and Leng 1987).

Figure 3.23. Relation between non-ammonia crude protein absorbed in the small intestine and crude protein concentration in dried and fresh forage (Minson 1990).

tropical grass and legume forages provide less by-pass protein than temperate forages and animals require energy and/or protein supplementation for high levels of production (Figure 3.24).
Figure 3.24. Predicted relationship between intestinal crude protein supply and crude protein content of condensed tannin-free forages consumed in the fresh state. Levels of dry matter digestibility (% DMD) and the likely range in values for tropical and temperate grasses and legumes are indicated (Poppi and McLennan 1994).

Animal production in northern Australia: an introduction

Beef production

Cycles of liveweight gain (LWG) in the summer wet season and loss in the winter dry season are typical for beef cattle fed mainly from pastures; compensatory weight gain early in the wet season also typically occurs after significant weight loss in the dry season (Figure 3.25).

Figure 3.25. Typical pattern of LWG by beef steers grazing average quality black speargrass pasture.

Liveweight gains and losses on these native pastures are closely related to the nitrogen concentration of pasture on offer and to the nitrogen concentration of the diet; a threshold of about 1.0 % N is required in the diet for transition from weight loss to weight gain (Figure 3.26).

- Dietary crude protein requirements for weight gain are influenced by the level of rumen degradability of the protein source; high and efficient daily liveweight gain is difficult to achieve when protein degradability is greater than about 70%.
Figure 3.26. Pasture quality attributes and LWG of steers grazing black spear grass pastures: (a) Relation between the proportions of green herbage in the diet and in the pasture; (b) Relation between the nitrogen content of green herbage and its age; (c) Relation between LWG and diet nitrogen (Hendrickson et al. 1992).

This explains the close relationship existing between LWG from native pastures and the length of the growing season in the seasonally, dry tropics where the transition between seasons and between green and dry feed is most abrupt (Figure 3.27).

Figure 3.27. Relationship between annual LWG and length of growing season in the seasonally dry tropics (Gillard 1979).

Deficiencies of essential minerals can have large impacts on production (Figure 3.28).

Figure 3.28. Influence of diet phosphorus on daily steer LWG in autumn (McLean et al. 1990).
The nutritional limitations of native pastures can be summarised as energy and N deficits in the dry season, and P and N deficits in the wet season.

Most improved tropical grass/legume pastures are unable to support the very high liveweight gains required to achieve 2 year turn-off of finished cattle at >300 kg, as demanded by the present premium markets for beef (see Chapter 5). To meet such markets, energy and/or protein supplements may be required on many of these pastures, even during their peak growth period.

**Dairy production**

Herd averages of milk production components per cow per lactation in northern Australia can range from 2500 to 10 000 L milk, 70 to 320 kg protein and 100 to 350 kg butterfat. However, milk yields in practice rarely exceed 7000 L.

The higher levels of milk production require high levels of nutrition year-round; these can be achieved through a combination of tropical pastures (summer), irrigated temperate pastures (winter), nitrogen-fertilised tropical/temperate grasses and forage crops, and supplements (hay, silage and grain) fed over most of the year.

The pattern of change in feed intake, liveweight and milk yield of cows between calvings is shown in Figure 3.29.

Figure 3.29. Patterns of feed intake, liveweight and milk yield over the lactation cycle (Broster 1983).

Examples of the relationships between milk production components and some forage and feed attributes are given in Figures 3.30 and 3.31.
Daily milk yields are depressed in summer when daily maximum temperatures exceed 25°C, probably due to a combination of heat stress and reduced grazing time and intake (Figures 3.14 and 3.32).

Figure 3.32. Association between daily milk yield of dairy cows and daily maximum temperature during summer (from data of Cowan et al. 1993).

In summary, the major limitations to milk production in the subtropical dairy environment of northern Australia are the supply of energy and forage protein, and heat stress.

**Wool production**

Most sheep in northern Australia are extensively managed for wool production in harsh, semi-arid and arid environments. Lamb finishing is limited and, where it is practised, is confined to the more favourable eastern margins of the Queensland sheep area, often in association with cropping lands.

Average annual greasy fleece weights produced in Queensland range from 3.8 to 4.3 kg per sheep, with clean wool growth rates being between 0.4 to 1.5 mg per cm² per day. Most wool is between 20 to 24 micron, fine to medium wool.

Typical seasonal patterns of wool growth in northwestern Queensland on mitchell grass pastures are characterised by peaks of growth within the mid-summer to late-autumn period (Figure 3.33).

Figure 3.33. Seasonal patterns of wool growth on mitchell grass pastures (Lorimer 1981).

This period coincides with pasture growth from seasonal rain. However, close relationships between wool growth, forage dry matter digestibility and forage protein content (see Figure 3.18) have still to be unequivocally demonstrated in this environment; this is probably because nutritious ephemeral plants that are commonly selected in the diet represent only a small proportion of the forage on offer (Lorimer 1978, 1981).

In summary, the major constraints to wool production are the extremely variable quality of forage within and between seasons.

**Animal reproduction**

The period from late pregnancy to peak lactation is nutritionally demanding (Figure 3.34).

Figure 3.34. Effect of physiological state on potential retention of nitrogen in relation to digestible organic matter intake (Orskov 1970).
Aspects of animal reproductive performance influenced by nutrition are the LWG of the dam, pregnancy rate, progeny birthweight, post-birth anoestrus interval, calf and lamb mortality, and milk production.

Some of the reproductive responses to nutrition are illustrated by those measured with beef cows and calves grazed on temperate pastures (Figures 3.35 and 3.36).

Figure 3.35. Influence of pre-calving pasture allowance in the last 8 weeks of pregnancy on daily cow liveweight change, condition score, post-calving anoestrus interval and calf birthweight (Nicol and Nicoll 1987).

Figure 3.36. Influence of post-calving (calving to joining) pasture allowance on post-calving anoestrus interval and pregnancy rate for low (L) and high (H) pre-calving pasture allowances (Nicol and Nicoll 1987).

Phosphorus deficiency may suppress feed intake by up to 50% and therefore can limit reproduction; low ovarian activity, conception rates, calving rates and branding rates are known to be associated with P deficiency.

Pregnancy and reproductive rates usually exceed 85% with high quality feed systems but may be as low as 30% with extensively managed animals on low quality forages.
References


