PROTEIN NUTRITION OF RUMINANTS IN TROPICAL AREAS
OF AUSTRALIA

D. W. Hennessy*

ABSTRACT

Beef cattle in northern Australia graze pastures which consist predominantly
of native grasses; in general these cattle lose weight from May to November. Whilst
the nutritive value of tropical grasses is low in senescent pastures, protein is generally
the nutrient in shortest supply relative to ruminant requirements, and more often
limits animal production than does the low metabolizable energy content of such
pastures. Ruminants have two sources of exogenous protein; microbial protein, and
dietary protein which escapes fermentative breakdown in the rumen. Microbial pro-
tein production in the rumen depends on the availability of energy, ammonium com-
pounds and minerals, including sulphur which is often low in tropical forages. The
amount of dietary protein which escapes rumen fermentation depends on types of
protein, rumen conditions and physiological state of the animal at the time of feeding.
However, protection of proteins from rumen degradation may be increased by heating
or treating them with chemical aldehydes. Additional information is required before
reliable guidelines for feeding protein can be implemented for cattle in tropical Aus-
tralia.

INTRODUCTION

Beef cattle production in northern Australia relies largely on native grasslands
(Rickert and Winter 1980). The seasonal growth pattern for cattle grazing native
pastures in the tropics was described by Norman (1965) who indicated that from
December to February, cattle at Katherine had rapid weight gains of up to 1 kg a
day, with slower gains (0.5 kg a day) from then until May. From May until
November, cattle lost weight. The growth pattern for cattle in the subtropics is
similar (Alexander and Chester 1956).

Tropical grasses grow and mature under a high temperature regime. High
temperatures stimulate growth and aging of grasses with a consequent fall in digesti-
bility (Deinum and Dirven 1975). Tropical grasses have a greater proportion of
their dry matter (DM) as cell walls, and generally have less soluble carbohydrate
than do temperate grasses. In addition, cell wall constituents are less digestible in
tropical than temperate grasses. Those features of tropical grasses responsible for
their low intake and energy digestibility were reviewed by Wilson and Minson
(1980).

NUTRITIONAL REQUIREMENTS OF RUMINANTS

Ruminant tissues, like those of other mammals, have requirements for specific
nutrients such as glucose and amino acids. However, unlike simple-stomached
animals, some specific nutrients need not be supplied in the diet of ruminants because
microbial fermentation in the rumen converts many ingested nutrients into new
products which upon digestion by the host yield specific nutrients which they require.

The quantity of amino acids absorbed by the ruminant depends largely on the
quantity of protein which reaches the intestine and is digested to amino acids. The
major exogenous supply of protein to the intestine of ruminants is microbial protein,
produced in the rumen especially by the bacteria. The other source of protein is from

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unfermented dietary protein (often termed "by pass protein") which reaches the intestine in a non-degraded form.

FERMENTATION OF PROTEIN IN THE RUMEN

Rumen bacteria attach themselves to ingested plant material and by the aid of their cellulase enzymes break down carbohydrate material. This action is aided by chewing which ruptures plant cells, thereby allowing bacteria access to a greater area of cell surface and to cell contents. The fermentation of the carbohydrates provides volatile fatty acids, a major energy source to ruminant animals, and releases ATP which is the energy substrate used by bacteria. For a healthy microbial population there has also to be adequate quantities of ammonia (McDonald 1952) and sulphur (Moir et al. 1967-8), which in the tropics may be limiting (Siebert and Kennedy 1972).

Limitations to microbial protein production

The main factor usually limiting microbial growth in the rumen is the availability of energy. Egan (1976) has summarised the relationship between energy (represented by forage digestibility) and nitrogen in the diet, and microbial growth. When ingested forage contained more than 25 g N kg⁻¹ DOM (digestible organic matter), N was generally in excess of that required by the microbes but when less than 13 g N kg⁻¹ DOM, N was generally insufficient. Whilst the N requirements of bacteria are often assumed to be met by ammonium compounds, there may well be a need for specific amino acids and peptides (Wright and Hungate 1967). If this occurs, then a source of soluble true protein in some rations will enhance microbial production above that due to N in the ammonium form. Even when microbial protein is at a maximum it may be insufficient to allow maximum animal production. Egan and Walker (1975) suggested that the truly digestible true protein of microbial origin would only support gains of 200 g day⁻¹ in young cattle and that a source of "by pass protein" was required for gains greater than 200 g day⁻¹. Similarly, Orskov (1977) concluded that the protein requirement for maintenance and growth of young steers of less than 200 kg liveweight, was not met by microbial protein.

Plant proteins and their rumen degradability

Plant proteins can be classified on the basis of the solubility of the total N. The solubility has been estimated in buffer solutions (Wohlt et al. 1973), or by the loss of N from material held in nylon bags suspended in the rumen (Mehrez and Orskov 1977). The insoluble fraction can be classified further into that which may be fermented in the rumen and to that which is not (Orskov and McDonald 1979). Degradability of soluble protein fractions in the rumen depends on the presence of proteolytic enzymes and on the structure of proteins, rather than on their degree of solubility (Nugent and Mangan 1978). Often there are few proteolytic enzymes in the rumen of sheep on low quality roughages (Hogan and Hemsley 1976) and degradation of proteins is slow or incomplete. Fermentation and hydrolysis of insoluble protein depends on a number of factors, including the type of diet and its effect on the fractional clearance of rumen contents, and the physiological state of the animal.

Estimates of protein degradability have been made by incubating diet samples in nylon (or synthetic-fibre) bags suspended in the rumen of fistulated sheep or cattle. Mathers et al. (1977) suggested from their studies that the nylon bag technique gave estimates of N disappearance similar to those obtained from measurements of non-ammonia N (NAN) flow, provided incubation times were short (4–6 hours). This disappearance of N, or degradability of N material in a bag, should be related to the residence time of the proteins in the rumen, and also to the flow of NAN of non-microbial origin to the duodenum for the technique to be meaningful. Some problems associated with estimating degradability have been discussed by Kempton (1980).
PROTEIN SUPPLEMENTATION IN TROPICAL AUSTRALIA

Non protein nitrogen (NPN)

There has been a number of trials in which the role of NPN supplements has been evaluated. Round (1976) reviewed 118 experiments and concluded that urea supplements had a beneficial effect on production when cattle were kept in pens or grazed mature native pastures in the tropics. However, there may be a difference between the tropics and sub-tropics. Responses by cattle, fed native pasture hay in pens, have been greater in the tropics than the sub-tropics (Table 1). In northern Queensland, grazing cattle supplemented with NPN during the winter have gained 250 g liveweight day$^{-1}$ more than unsupplemented cattle, and after calving in late winter have had from 10 to 12% higher conception rates (Durand 1978).

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tr>
<td><strong>Effect of urea, or urea and molasses supplements, on the intake of native pasture hay of penned cattle.</strong></td>
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<tr>
<th>Hay quality</th>
<th>Intake (g day$^{-1}$)</th>
<th>Hay intake (% change)</th>
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<tr>
<td>Nitrogen (% DM)</td>
<td>metabolizable energy (MJ kg$^{-1}$ DM)</td>
<td>urea</td>
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<tr>
<td><strong>Tropics</strong></td>
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<tr>
<td>S. R. McLennan†</td>
<td>0.37</td>
<td>5.3</td>
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<tr>
<td>J. A. Lindsay†</td>
<td>0.36</td>
<td>5.9</td>
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<tr>
<td><strong>Subtropics</strong></td>
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<tr>
<td>Cohen (1974)</td>
<td>0.61</td>
<td>6.2</td>
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<tr>
<td>Hennessy <em>et al.</em> (1978)</td>
<td>0.58</td>
<td>6.6</td>
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†unpublished data.

Legume nitrogen

Tropical plants with the C4 photosynthetic pathway have a high proportion of their protein in bundle-sheath cells which are so toughened that they afford natural protection to rapid solubilizing of protein in the rumen (Brady 1976). Whilst the tropical legumes do not appear to be different in this respect to temperate legumes (Wilson and Minson 1980), some tropical legumes are accredited with having part of their protein in a protected form. In the study of Flores *et al.* (1979) the total N of leaf (and fine stem) of *Leucaena leucocephala* was less soluble (21% of total) than that of N-fertilized Rhodes grass (32%). When dairy cows grazing a Rhodes grass (3% N in DM) pasture were given small quantities (2 kg day$^{-1}$) of leucaena leaf each morning, daily yields of milk, butterfat and casein were increased by 7%. At Brian Pastures Research Station, Hereford weaners with access to leucaena during the winter, gained 160 g day$^{-1}$ when grazing a native grass pasture but those without access to leucaena lost 200 g day$^{-1}$ (A. H. Foster and A. Laing, unpublished data). Since NPN supplements did not reduce the rate of liveweight loss of other weaners at Brian Pastures it indicates that the response due to N in leucaena was from the less soluble or “by pass” protein fraction.

Leaf, seed and pod of tropical legumes are a useful source of N to cattle during the ‘dry’ season (Norman 1970), especially since some of the N may be protected from rumen degradation. For example, samples of seed and pod of *Stylosanthes humilis*, which contained 5% N, had 30% of the total N remaining after 20 hours’ incubation in the rumen (Playne *et al.* 1972). Tannins, which occur in *Lespedeza cuneata* and *Desmodium intortum* apparently afford protection to some of the proteins in these plants (McLeod 1974). On the other hand, the reason for the protein protection in leucaena is not known.
Protected protein

Protection of proteins from rumen degradation may be increased by heating or treating them with chemical aldehydes viz. formaldehyde (see Ferguson 1975). Stobbs et al. (1977) increased milk yield by 20% in Jersey cows grazing on N-fertilized Rhodes grass pasture by dosing daily with 1 kg of formaldehyde-treated casein, whereas untreated (soluble) casein increased milk yield only by 3%. At Wollongbar, a small increase (7%) in milk yield was obtained when formaldehyde-treated soya bean meal replaced 1 kg of a 4 kg daily wheat supplement. This increase was no greater than that (3%) due to untreated casein replacing part of the wheat in the supplement (A. Ashwood and J. Hogan, unpublished data). The heifers were in mid-lactation and the small responses to casein, either unprotected or protected from rumen fermentation, indicate that protein was not limiting production in the heifers as it was in the case of cows in the experiment of Stobbs et al. (1977).

Liveweight losses of cattle eating a native pasture hay were prevented by feeding a supplement of urea + sulphur at “Swans Lagoon”, North Queensland. When formaldehyde-treated casein was fed liveweight gains were linearly related to the quantity of casein consumed. Gains of up to 120 g day⁻¹ occurred when 220 g treated-casein was added to the daily hay ration (J. A. Lindsay and I. A. Loxton, unpublished data).

Protein supplements which contain some protected protein

Cottonseed meal generally contains insoluble protein-complexes formed when the oil is extracted from the cottonseed. Liveweight responses by cattle to supplements of cottonseed meal in the tropics have been reported by Alexander et al. (1970) and Siebert et al. (1976). However, studies have not separated the response into that due to soluble or non-degradable protein or indeed to other nutrients (e.g. starch) which the meal may contain. In some cases, most of the proteins in cottonseed meal are highly soluble in the rumen. Very high rumen ammonia concentrations (up to 720 mg NH₃–N litre⁻¹) have been detected in young dairy calves at Ayr within hours of feeding indicating that many of the proteins were soluble or degraded rapidly (R. J. Moss, personal communication).

On the other hand, when a less soluble protein meal, consisting predominantly (up to 80%) of cottonseed meal, was offered during winter to steers grazing a native pasture at Grafton, the rumen ammonia concentrations increased only moderately (to 55 mg NH₃–N litre⁻¹) and liveweight increase was 370 g day⁻¹ compared to a daily loss of 50 g day⁻¹ in unsupplemented steers (Hennessy et al. 1981). Heifers grazed the same area of native pasture the following year and were offered the same protein meal as the steers, but at a higher daily rate (800 g v 600 g). Supplemented heifers gained 500 g day⁻¹ during winter compared to unsupplemented heifers which lost 75 g liveweight day⁻¹. As a consequence of the higher liveweight at mating (at 15 months of age), 92% of the supplemented heifers calved in the following August, compared with none of the unsupplemented heifers (D. W. Hennessy, unpublished data).

FEEDING PROTEIN IN THE FUTURE.

Up to the present, requirements of protein by ruminants and the protein value of feed have been expressed as apparent digestible crude protein (DCP) i.e. the difference between the quantity of crude protein in the feed and in the faeces. Whilst the system is a simple one, it does not indicate the capacity of different feedstuffs to supply protein in dietary or microbial forms to the small intestine of ruminants. Before we can propose guidelines for tropical Australia which adequately describe the specific protein requirements of different classes of ruminants, and the capacity of feed to meet these requirements, we need to fill the following gaps in our knowledge:
The physical form (e.g. leaf and stem) and chemical properties (e.g. soluble ash, soluble carbohydrate, lipid, amino acids) of tropical forages need to be described. These differ, often strikingly, from temperate forages and throughout the growing season. Such descriptions would provide a sound basis of understanding of forage quality as it affects ruminants.

Digestion of feed organic matter (OM) in the rumen reflects the quantity of energy available for microbial protein synthesis. This digestion is not a constant fraction. The range for a number of forages and grains was from 26–55% for a range of digestibility of 44–88% (Ulyatt and Egan 1979). Ideally, the proportion of OM apparently digested in the forage should be known for many of the commonly grazed tropical forages, during at least the “dry” or cool seasons, and wet summers.

There may be an important contribution of recycled N to the ammonia pool in the rumen of cattle eating low protein forages, or forages in which protein is insoluble or highly protected. Mature cows have extensive reserves of labile N (Paquay et al. 1972) whereas for young or lactating cows the reserves are probably less. Obviously, the contribution of recycled N to microbial protein synthesis in the rumen should be established for different classes of stock on low protein forages, or forages in which much of the protein is insoluble.

Values for the efficiency of rumen microbial synthesis vary widely e.g. 15–45 g N kg⁻¹ digestible OM fermented. Reasons for the range need to be understood so that the quantity of microbial protein produced in the rumen can be estimated for cattle of different ages or class, and for forages which they consume.

Protein requirements may also be increased when there is extensive breakdown of microbial cells (e.g. protozoal predation of bacteria) and where there are increased losses of nitrogen of metabolic origin. Up to 60% of protein requirements can be due to replacement of N lost as metabolic faecal N (MFN) (Egan and Walker 1975) and as yet there are no data which indicate how much is lost when cattle ingest mature tropical forages.

The extent of degradation of dietary proteins has to be defined for different forages and different classes of stock before any comment can be made on the quantity of protein which “by-passes” rumen fermentation and reaches the small intestine. The nutritive value of the “by pass protein” is often assumed to be similar to that of the original proteins. This may not be so, and the nutritive value (due to losses of some amino acids) of “by pass proteins” may need to be discounted.

The points discussed above refer to a proper understanding of the characteristics of the forages and the protein requirements of various classes of stock. Obviously, it will be some time before we have knowledge of all the parameters and in the interim we need a simple guide. Moir et al. (1970) suggested that faecal protein contents might be used to predict additional protein requirements of grazing cattle. However, faecal N is a measure of the digestibility of forage (Lancaster 1949) and therefore as digestibility increases, so does the output of faecal N. Unless the relationship is standardized for each forage grazed, faecal N may be unreliable as an N intake. For older, non-lactating animals the ratio of N:DOM in the forage is a reliable guide to whether there is sufficient N for optimum microbial synthesis, as discussed by Egan (1976). However, this does not apply to forages of low digestibility (<45% DMD) in which case energy limits microbial synthesis.

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REFERENCES


