FACTORS AFFECTING NITROGEN REQUIREMENTS FOR RUMINANTS AND CONDITIONS DETERMINING THE NEED FOR SUPPLEMENTAL N IN CATTLE AT PASTURE

INTRODUCTION

D. W. HENNESSY*

Australia's sheep and cattle industry rely on a year-round grazing of pastures for their supply of nutrients. However, most areas suffer from a seasonal dry period which often extends into the normal growing season. During these dry seasons the pasture remaining drops in quality, especially in its content of energy and nitrogen (N) or protein. As a consequence, feed intake declines and production and liveweight of the grazing ruminant drop markedly. But considerable dialogue, and some controversy, have occurred in Australia, and elsewhere, as to what is the primary limitation to production of ruminants when N intakes are low and indeed as to what is the most appropriate form of N when offered as a dietary supplement.

This contract reviews the conditions operating within the ruminant that determine the supply of protein to the tissues from the intake of simple or complex forms of N, and how this supply can be affected by the animal and type of forage available in divergent areas of Australia. The first three papers examine the conditions that favour microbial protein synthesis in the rumen, the supply and digestion of proteins in the intestine and the effect of absorbed amino acids, or changes in plasma urea concentration, on recycling of urea to the rumen. The final three papers discuss the requirements of N by ruminants in a temperate, sub-tropical and a sub-humid tropical area. The summary attempts to integrate the fundamental knowledge with the results from the grazing studies to highlight the role of N in ruminant diets and how best any deficiency can be overcome.

FACTORS AFFECTING PROTEIN SUPPLY TO THE SMALL INTESTINE

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The principles governing the supply of protein to the ruminant small intestine are well known - the dependence on protein intake, the extent of microbial protein synthesis in the rumen and the proportion of dietary and microbial protein that is degraded before departure from the stomach. However, the producer needs to know if the amount of protein reaching the intestine is adequate to match the energy available to the animal and if inadequate, what he can do to improve the situation. Both in the gut and tissues, protein and energy metabolism are closely inter related but this paper can consider only those interactions as they affect the amount of protein that passes from the stomach. Energy will be described in terms of the intake of digestible organic matter (DOM) which not only gives an indication of the energy that becomes available to the rumen microbes but also is closely related to the metabolizable energy derived by the animal. Protein will be considered as crude protein (N x 6.25, = CP) even though 20% or more in feed and microbes is probably in forms other than amino acids.

Factors affecting protein supply

(1) Protein intake. Protein intake is a function of CP/kg organic matter x organic matter intake. Feed intake and CP levels tend to be high with young plants but decline with advancing maturity. With temperate species, as cell wall content increases from 40 to 85% of plant organic matter, CP levels decline from

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30% to 5% and CP intakes by sheep from 300 to less than 50 g/d. Tropical species tend to have higher levels of cell wall and lower levels of CP, so feed intake and hence CP intake are probably lower at a given stage of maturity than for temperate species. However, digestibility also declines rapidly and the DOM:CP ratios may not differ greatly between the two forage types.

(ii) Breakdown of plant proteins. Plant CP degradation depends on the physical nature of the proteins, their rate of release from plant cells, the concentration of proteolytic enzymes and the time available for proteolysis. About half the proteins in temperate plants may be soluble, the other half attached to membranes. Although only about one third of the plant cells are ruptured during the initial chewing, most cells, except the cuticle, are susceptible to bacterial attack if they stay long enough in the rumen. By contrast, with tropical forages more than 20% of plant proteins are present in structures such as the vascular bundle sheath which is resistant to microbial attack. Tannins, present in many tropical species, may also denature proteins and inhibit microbial attack. With vegetative temperate forages, 75%, or more, of the plant protein may be degraded in the rumen, though this proportion can be reduced by accelerating the passage of protein through that organ. The few corresponding values for tropical forages are of the same order, though the data are not adequate to support firm conclusions. With mature plants, sufficient protein may be associated with the cell wall to reduce the amount available to either the rumen microbes or to the host: if this should be so the more fibrous tropical species may be relatively more protein deficient than the temperate species. However, on a broad scale, variations between species are not apparent because for a given CP content, the digestibility of CP in the whole tract with both temperate and tropical spp, does not differ significantly (Minson 1982).

(iii) Microbial protein synthesis. Microbial protein synthesis requires ammonia or amino acids, minerals such as sulphur and phosphorus, and energy in the form of high-energy phosphates released during carbohydrate fermentation. Protein synthesis in forage-fed animals is inhibited at levels of rumen ammonia somewhere below 50 mg/L; this is observed in forages with DOM:CP ratios above 8 or CP contents of less than 6%. The theoretical reasons for this involve energy transactions in the rumen. The organic matter fermented in the rumen averages about 68% of DOM intake though values as low as 40% and as high as 80% have been reported with mature forages; average values for microbial protein synthesis are 200 g CP (32 g N)/kg DOM. A roughage with an organic matter digestibility of 50% would need 61 CP to meet the requirements of microbes for nitrogen. In practice, it is unlikely that all plant nitrogen becomes available to the rumen microbes, as indicated earlier; however, any deficit is met at least in part from the urea and protein recycled from blood to rumen either directly or in saliva (see paper by Norton; this review).

(iv) Fate of microbial cells. Microbial cells and their contained proteins face degradation before they leave the rumen. Bacterial protein yield reaches its highest efficiency if the bacteria are "harvested" by passage to the intestine as soon as the cells reach mature size following division. Any delay exposes cells to destruction by lysis or attack by viruses or protozoa. Protozoa incorporate bacterial protein into their own cells but the yield to the animal is reduced in the inefficiencies of conversion and because of the longer time spent by protozoa in the rumen. The removal of protozoa is likely to improve protein supply to the animal by about 10% with forage diets but more with concentrate diets where protozoa may constitute three quarters of the rumen biomass.

The mean residence time spent in the rumen by small particles including bacterial cells can be artificially reduced by increasing water flow through the
rumen with high salt intakes. Residence time is also reduced and protein supply improved in consequence of a reduced rumen volume per unit feed intake in late pregnancy and as a result of increased feed intake in animals during lactation and in the cold. It might be expected, conversely, that the flow of protein would be reduced in animals exposed to heat stress. If that is so, species such as the Bos indicus which are relatively tolerant to heat stress should, on a given diet, have a better protein supply than Bos taurus.

Estimation of protein reaching the intestine

With wethers fed dried temperate forages, CP reaching the intestine (g/d) = 0.16 DOM intake + 0.36 CP intake + 6 (Hogan and Weston 1981). This relationship does not differ significantly from that derived from studies with grazing wethers (Corbett et al. 1979) and is valid for mature tropical grasses, though such grasses at a vegetative stage have not yet been studied. Deviation between measured and predicted values within the range of DOM:CP ratios between 4 and 9 is small. Deviation beyond 9 can largely be corrected by supplementation with urea and minerals. More extensive deviations from the predictive relationship occur with diets in which DOM:CP is less than 3.5. These are forages with high levels of nitrogen, varying proportions of which may be present in non-protein form and the total amount of protein passing to the intestine may vary between two grasses, with the same DOM:CP ratio of 3.5, from 80 to 100%, depending on N losses in the rumen. However, these are plants with more than 35% CP and a greater wastage of protein than anticipated might not be very important nutritionally. As might be expected, the relationship predicting CP flow under-estimates the amount in situations where mean residence time in the rumen is reduced through pregnancy or increased feed intake. The error is probably about 10%. An over-estimate of similar magnitude may be observed with diets containing a large amount of soluble nitrogen relative to readily fermentable carbohydrate such as provided by lucerne or grass silages. However, with a little care, the relationship can provide a reasonable practical basis for decisions on the need to supplement a diet with non-protein nitrogen.

THE ROLE AND MODES OF ACTION OF INTESTINALLY DIGESTED DIETARY PROTEIN

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Dietary protein and non-protein nitrogen (NPN) from various sources lead to production of ammonia, and to the synthesis of microbial protein. Dietary protein may also escape ruminal fermentation by virtue either of its rapid passage or of its physico-chemical condition which retards microbial proteolysis. The question to be addressed here is: To what extent and on what types of herbage diet is a supplementary protein component an essential complement to microbial protein, to provide essential amino acids at the small intestine, to remove a primary limitation to rapid growth, or to lactation? Information derived using the sheep is supported for cattle only by limited tests where response to nutritional treatments indicate similar mechanisms are operating.

The contributions of dietary protein digested in the small intestine

Dietary protein is digested in the small intestine on many herbage diets and on roughage diets supplemented with protein-rich concentrates. This is not restricted only to proteins that have been extensively denatured or to proteins chemically treated to reduce their susceptibility to proteolysis under the conditions present in the reticulo-rumen. The amounts of protein or of amino acids flowing to or disappearing from the small intestine, and the proportions attributable to microbial and to dietary proteins, have been discussed. (See paper by Hogan; this review.) The contribution made collectively by these fractions may

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be adequate to meet the amino acid requirements of the animal, but calculations (e.g. Egan and Walker 1975; ARC 1980) indicate that there are dietary circumstances in which growth rate or production level are limited primarily by essential amino acid inadequacy. Supplemental proteins can alter N conditions in the reticulo-rumen affecting microbial protein synthesis and/or rate of fibre digestion, but also can provide additional amino acids at the small intestine. Any response to the latter contribution arises through two possible avenues. First, the extra essential amino acids absorbed may help to overcome specific amino acid deficiencies which are limiting production. Second, the extra amino acids may be absorbed, catabolized and improve the supplies of energy, gluconeogenic substrates, and recycleable N, such as urea. The last mentioned can then enhance ruminal N status; an avenue of action shared by dietary protein or NPN slowly degraded in the rumen.

Distinguishing the modes of action of protein supplements

If energy provision is the factor limiting production, any form of digestible energy should suffice, whether it be an additional source fermented in the rumen or digested in the intestine, or an enhancement of digestion or intake of the basal diet. That protein can satisfactorily accomplish such changes does not rule out alternative strategies. However, if essential amino acids are the primary factor, only extra protein digested in the small intestine can result in improved production. The extra protein may not be attainable from improved microbial growth in which case supplemental protein digested in the small intestine is necessary. Improved production can then occur because of increases in intake, changes in kinetics of flow of digesta influencing the site of digestion of dietary materials, and/or improvement in efficiency of use of ME associated with repair of the nutrient deficiency. Grazing systems in which it is possible that essential amino acid inadequacy is a primary cause of a low level of production include those utilizing crop residues or grass pastures approaching maturity.

If the protein requirement is expressed in terms of absorbed amino acids it has been estimated (e.g. Egan and Walker 1975) that on many roughage diets, methionine, threonine and possibly isoleucine are those in relatively shortest supply. A series of experiments was undertaken to test the influence of intestinally absorbed amino acids as opposed to ruminally degraded N, recycled N or gluconeogenic substrates. It is clear that N retention and intake can be improved by protein sources which provide essential amino acids for absorption from the small intestine on diets yielding less than 5.5 g intestinally digested protein/MJ DE. Recent experiments with sheep which have contributed to these statements form three series:

(i) On wheaten straw, barley straw, or mature ryegrass (chopped or ground and pelleted) supplemented with NPN in the form of urea, abomasal infusion of methionine and threonine has led to increased intake and to increased nitrogen retention (Fennessy 1976). Abomasal supplementation with equivalent amounts of non-essential amino acid or N gave no response.

(ii) On diets of mature ryegrass (chopped, or ground and pelleted) infusions of mixtures of amino acids into the small intestine have led to improvements in nitrogen retention and in appetite only when methionine, threonine and isoleucine were included in the mixture. Depending on the level of infusion, if those essential amino acids were excluded from the mixture infused, intake and N retention can be depressed (Fennessy 1976), resembling a classic imbalance response (Egan and Rogers 1978).

(iii) Ground, pelleted wheaten-chaff (N content 0.9 – 1.2%), supplemented with minerals and urea was fed to sheep which were then given oral supplements of
formaldehyde-treated casein, formaldehyde-treated gelatin or of formaldehyde-treated gelatin complemented by an abomasal infusion of lysine, methionine, threonine and isoleucine to approximate the essential amino acids contained in casein. The following responses were observed (Nottle 1982): casein resulted in an increase in N retention and appetite. Gelatin, providing similar amounts but a poorly balanced pattern of intestinally digestible amino acids resulted in a small increase in intake. The addition of the 'missing' essential amino acids further increased both intake and N retention to levels not significantly different from those of the animals fed casein.

Intra-ruminal N release or recycling of N to the rumen could not have contributed to responses in these three sets of experiments as there were no differences in ruminal N inputs, ruminal ammonia concentrations or plasma urea concentrations (see paper by Norton; this review). The response to small additions of specific essential amino acids indicates that the response is related to the repair of a deficiency among absorbed essential amino acids. The differences in energy provision or in gluconeogenic substrate provision were equivalent across the respective treatments.

Conditions where intestinally digested protein can be effective

Findings with sheep across many experiments indicate that only when the PE value falls below 5.5 g of intestinally digested protein/MJ DE will consistent responses in N retention and intake be obtained with intestinally digested protein in young growing sheep. Definitions for animals in other physiological conditions need now to be derived. Preliminary estimates for responses in beef cattle depend on limited measurements of flow of protein in the small intestine where positive responses to protein supplements have been observed. So far this is restricted to crop residues and mature grasses where 4.5 g - 6.0 g of intestinally digested protein/MJ DE is encountered. In N supplementation studies with cattle where intensive measurements cannot be made it is important that adequate control treatments be used to differentiate between mechanisms of response; for example:

1. NPN may be incorporated in such a way that no advantage arises from increased ammonia availability in the reticulo-rumen, or,

2. Equal intakes of a poorly balanced 'protected' protein supplement can be provided.

A positive response indicates mechanisms other than direct repair of an essential amino acid deficit. Similar responses may occur with supplements of ruminally degraded N sources or with supplements of energy. When no response occurs it suggests that the limitation is due to an inadequate supply of essential amino acids. Work with sheep in the experiments described above show that it is possible to achieve the conditions needed to test these hypotheses, using gelatin, bloodmeal or other proteins low in one or more essential amino acids that are limiting intake on the basal diet.

THE PRACTICAL SIGNIFICANCE OF NITROGEN RECYCLING IN RUMINANTS

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The ability of ruminants to survive under harsh environmental conditions has been attributed to their capacity to conserve urea at the kidney for recycling to the digestive tract for re-utilization by the resident microbial population. However, the quantitative significance of this mechanism for long term survival
must be questioned since grazing ruminants consuming low quality pastures often require additional nitrogen (N) supplements to prevent severe weight loss, suggesting that recycling is inadequate under these circumstances to meet even body weight maintenance.

In the past decade, the extent and significance of recycling in sheep and cattle given a variety of diets have been intensively studied, and this review attempts to provide a contemporary view of the possible significance of endogenous recycling of metabolites to the grazing ruminant. Evidence for the significance of recycling to the rumen during periods of dietary N deficiency come from two sources; firstly, there is usually a substantial net gain of N between amount eaten and amount presented for absorption at the intestines, and secondly, that as the protein content of the diet decreases an increasing proportion (but decreasing amount) of urea synthesized is apparently degraded in the digestive tract.

When there is sufficient energy available for fermentation, the recycling of endogenous metabolites to the digestive tract will only be significant to the animal in the following circumstances:

(a) when they enter the rumen pool and are available to the microbial population
(b) when they provide additional amounts of the nutrient that is first limiting microbial metabolism.

Endogenous metabolites may enter the rumen by three routes: through saliva, across the rumen wall and as desquamated cells from the rumen epithelium, although secretions from the omasum and abomasum, which are usually included as part of the N gain across the rumen, cannot be considered as part of the recycling pathway. Secretions into the rumen contribute not only N (as urea, amino acids and proteins) but also sulphur, phosphorus and other minerals. Where the feed consumed fails to provide that balance of nutrients essential for effective microbial activity, then endogenous recycling may significantly contribute to the maintenance of rumen function.

(i) Diet and recycling. The rate at which urea is recycled to the digestive tract of ruminants and degraded has been shown to vary with the protein content of the diet, the presence of readily fermentable carbohydrate in the rumen, the level of digestible organic matter intake, the age of the animal and with time after feeding. It seems that for sheep on low quality roughages (Norton et al. 1978, MacRae et al. 1979) the presence of readily fermentable carbohydrate in the rumen, the level of digestible organic matter intake, the age of the animal and with time after feeding. It seems that for sheep on low quality roughages much (80 to 90%) of the urea synthesized is degraded in the digestive tract but only a small proportion (10 to 25%) of the degradation occurs in the rumen (Norton et al. 1978, MacRae et al. 1979). In cattle given a low quality roughage, 20 to 50% of the total degradation may occur in the rumen (Norton et al. 1979) but in both species, urea recycled to the rumen only increased total N availability by 10 to 15% (i.e. from 0.5 to 1.5 g N/kg DMI). Since increased recycling to the rumen on these diets did not increase either feed intake or N retention it did not indicate any productive advantage under these conditions.

The inclusion of readily fermentable carbohydrate sources, such as sucrose and processed grain, has generally increased the rate at which urea is recycled to the rumen. Including 500 g sucrose into a spear grass diet increased the proportion of total urea synthesis degraded in the rumen of cattle from 59 to 73% and increased the rate of urea recycling to the rumen by 50%. The increase in urea degradation in sheep when 30% flaked barley was included into a pelleted grass diet was from 24 to 57%, although urea synthesis was reduced (Norton et al. 1982).

(ii) Saliva contribution to recycling. The evidence suggests that for ruminants consuming low quality roughages (<10 g N/kg DM) the major route of urea entry
into the rumen is through salivary secretions alone. For sheep, from 0.4 to 1.6 g N/d (Norton et al. 1978) is added to the rumen by urea recycling and this quantity can be accounted for by plasma urea concentrations (50 to 150 mg N/L) and estimated salivary flow rates of 10 to 15 L/d; similar conclusions can be drawn for cattle, assuming flow rates of 100 to 150 L/d. However, as noted earlier, N recycled to the rumen through saliva adds 0.5 to 1.5 g N/kg DM consumed and is only a minor addition to total N intake. On the other hand, saliva is the major route by which sulphur enters rumen fluid (Bray and Till 1975) and up to 4 and 234 mg are recycled daily in sheep and cattle respectively when fed spear grass hay (Kennedy et al. 1975). When these values are compared with the N recycled, ratios of N:S greater than 80:1 are found for sheep and 20:1 for cattle indicating that the efficiency of use of recycled N for microbial protein synthesis may be limited by the availability of S since the optimum N:S ratio is 10:1.

(iii) Recycling through the rumen wall Initial evidence for urea transfer across the rumen wall came from studies with in vitro or temporarily isolated rumen preparations but Hecker and Nolan (1971) measured arterio-venous difference of urea across the rumen of conscious, feeding sheep and concluded that less than 1 g of urea N was transferred across the wall. More recently isotope dilution techniques have allowed estimations of urea transfer to the rumen in feeding animals and it would seem that the quantities transferred are greater than can be accounted for by salivary secretion alone. The work of Norton (1982) indicated that the addition of digestible carbohydrate sources to low quality diets, and the products of digestion (e.g. butyric acid), can substantially increase (up to 200%) urea passage through the rumen wall. Possibly, urea entry into the rumen may be altered by addition of supplements to diets.

(iv) Endogenous protein secretion The shedding of epithelial cells into the rumen may be the major addition of protein N during metabolism but few studies have been made of the quantitative significance to the rumen protein pool. In sheep, Kennedy and Milligan (1980) estimated that saliva and cell sloughings, and gastric secretions, added 5 g of endogenous protein N/kg DM to intestinal flow and in calves the corresponding addition was 8 g/kg DM (Hart et al. 1982). Further studies are needed to define the amount of N contributed to ruminal N metabolism and to the flow of protein to the intestines from endogenous protein sources. This information is required for an accurate calculation of dietary protein degradability in the rumen from digesta flow studies.

(v) Control of endogenous recycling The recycling of N in saliva is a function of the rate of salivary secretion and of urea concentration in saliva. Factors which alter salivary flow rate, such as feed intake and proportion of roughage in the diet, will also affect the amount of urea recycled to the rumen. Since plasma urea concentrations are directly related to salivary urea concentrations (Somers 1961), dietary factors that increase plasma urea such as rumen ammonia concentrations and amounts of protein absorbed from the intestines will also increase the rate of urea recycling to the rumen. The fact that there is a correlation between blood urea and ruminal ammonia concentrations has been interpreted by some workers as evidence that rumen ammonia concentrations regulate the entry of urea into the rumen. However, low rumen ammonia concentrations are not often associated with high rates of recycling to the rumen (Norton et al. 1978, MacRae et al. 1979, Kennedy 1980), nor do high rumen ammonia concentrations necessarily inhibit urea recycling (Norton et al. 1982). Apart from the obligatory additions of urea through saliva, urea entry into the rumen is related to plasma urea concentration and the permeability of the rumen wall to urea. The addition of soluble carbohydrates to a diet can significantly increase the permeability of the rumen wall to urea, and it has been further suggested that permeability is related to changes in physical integrity caused by an interaction between fermentation end products, microbial activity in the rumen wall and the rates of epithelial cell growth and
Animal Production in Australia Vol. 15.

CONDITIONS DETERMINING THE NEED FOR SUPPLEMENTAL NITROGEN BY CATTLE GRAZING DRY FORAGE IN TEMPERATE AREAS

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The temperate areas of Australia are dominated by a Mediterranean-type climate that supports a growing season extending, on average, from May to November. As a consequence, beef production has traditionally been matched to the seasonal pattern of pasture growth, with calving in the autumn, and weaning calves in early summer for slaughter as vealers, or fattening in the following growing season.

Such management has accepted that December to April is a period when the available paddock forage consisting of dry, mature, annual pasture or crop stubbles — (wheat, barley, oats, triticale, lupins, peas) is only a maintenance feed for cattle. There is ample evidence that unsupplemented cattle on such dry forage only at best maintain weight, irrespective of stocking rate or forage availability.

The conditions that determine the need for supplemental N by cattle grazing dry forage can be discussed in terms of: type of production; type of forage and type of supplement.

**Type of production**

Any departure from the traditional pattern of beef cattle production could well have the financial incentive of marketing beef out-of-season on to higher-priced markets. Conversion of the dry period from a time of maintenance to one of production could, for example, enable:

* calving during the summer
* faster growth of breeding replacements from weaning to actual use as breeders
* faster growing-on of store weaners for earlier marketing.

**Type of forage**

Voluntary consumption of dry forage declines with decreasing crude protein (CP) content, decreasing digestibility and decreasing availability. The two basic types of dry forage can vary considerably in these three factors.

(i) Mature, annual pasture Typical mature, annual pasture of Wimmera rye grass, sub clover and barley grass can range from 5 to 10% CP and 40 to 50% Dry matter digestibility (DMD).

(ii) Annual crop stubbles The nutritive value of crop stubbles can vary substantially, due mainly to their content of spilt grain and weeds. Cereal stubbles can range from 3 to 7% CP and 35 to 45% DMD, whilst grain legume stubbles (such as lupins and peas) can range from 6 to 11% CP and 45 to 55% DMD. (Allden, 1982; Mullholland et al. 1976.)

Of the two, crop stubbles generally provide more dry matter (DM) per ha, with average availabilities ranging from 3 to 8 t DM/ha for crop stubbles, and 1 to 4 t DM/ha for mature, annual pastures.

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The three basic types of supplements that might be expected to improve the production of cattle grazing dry forages are energy (cereal grain-based), non-protein nitrogen (NPN) or protein supplements.

The ratio of supplement fed to growth response (response ratio) is a convenient means of assessing the biological and economic effectiveness of supplements fed to cattle grazing dry forage. This ratio readily indicates how a supplement has affected voluntary intake of forage. For example, if no substitution occurs, a supplement of 1.5 kg DM (with a M.E. of 10 MJ/kg DM) should produce a growth response of about 500 g/d in a 250 kg beast. This is a response ratio of 3:1 and provides a good standard for comparisons. Any response ratio less than 3:1 indicates that a supplement has stimulated appetite for the basal forage, and greater ratios indicate substitution of the supplement for the basal forage.

If the aim of supplementary feeding is to substantially increase beef production from dry forage, then the influence of the supplement on appetite for dry forage is of critical importance.

(i) Energy supplements Usually energy supplements have produced growth responses, but often with relatively inefficient use of the supplement. Response ratios have ranged from 5:1 to over 20:1 (Allden, 1982).

(ii) NPN supplements Despite many attempts, to date there have been no encouraging responses to NPN supplements fed to cattle grazing either mature, annual pasture, cereal stubbles or standing cereal crops in temperate areas of Australia (Smith, 1974; Allden and Tudor, 1976; Barker and May, 1978; G. H. Smith, unpublished data). This work covers urea, biuret and IBDU (iso butylidene di-urea) as NPN supplements.

(iii) Protein supplements Protein supplements that have been fed to cattle grazing dry forage in temperate areas include lupins, linseed meal, cottonseed meal and beans (Vicia faba). Generally, these supplements have been more efficient in promoting liveweight gain than have energy supplements.

The inclusion of 25% linseed meal improved the response to an oat supplement from 0.60 to 0.97 kg/d for young steers grazing dry hay aftermath (Morgan and Saul, 1976). In various experiments involving cottonseed meal supplements, response ratios of about 2:1 were consistently obtained for yearling steers grazing either mature, annual pasture or oaten stubble. Steers grew better on oaten stubble than on mature pasture (G. H. Smith, unpublished).

Cattle grazing wheat stubble and fed a bean supplement, grew 0.68 kg/d better than controls, giving a response ratio of 1.5:1 (W. G. Allden; unpublished data). However, in situations where yearling steers grazed mature pasture and were given a lupin supplement, response ratios were about 4.5:1 (Hawthorne 1980) and 3.2:1 (G. H. Smith; unpublished data).

Discussion

Egan (1977) suggested that when diets provide in excess of 6 g of intestinally digested protein/MJ DE then no additional response to dietary, bypass protein could be expected. This value would not be reached in many situations of cattle grazing dry forage in temperate areas. The amount of intestinally digested protein/MJ DE could presumably be increased by increasing the efficiency of microbial protein production, possibly by the use of slow-release, urea compounds. As yet, there is no evidence to demonstrate that such supplementation can produce
consistent, sizeable responses in the field.

Ultimately, economics dictate whether cattle should be supplemented whilst grazing dry forage. Economics will also decide the appropriate supplement, but on evidence to date, bypass protein supplements are the most biologically efficient in terms of effective utilization of dry forage by grazing cattle.

CONDITIONS EXISTING IN THE COASTAL SUBLTROPICS THAT DETERMINE THE NEED FOR SUPPLEMENTAL NITROGEN FOR CATTLE GRAZING NATIVE GRASS PASTURES

D. W. HENNESSY

Most of the beef cattle in the coastal subtropics of Australia graze grassland areas that consist predominantly of native or naturalised grasses. These grasses use the C4 pathway for photosynthesis and have in common the features of low digestibility (40-60% organic matter basis) and low nitrogen (N) contents (4-10 g N/kg DM) but conversely have high cell wall (700 g Neutral Detergent Fibre/kg DM) and lignin (130 g/kg DM) contents.

The subtropics differ from the tropics in the occurrence of winter with frosts, fogs, heavy dew and rain. It is during winter that plant growth ceases and nutrient content declines; the extent depending on the severity of frosts and the frequency of rain. A decline in cattle production follows the decline in plant quality, with young, British-breed cattle losing weight from June to October and having only low rates of reproduction.

In this paper, an attempt is made to describe the important parameters in cattle that indicate low levels of productivity, the methods used to initiate production responses and to comment on the mode of action of successful strategies. All of this is based on research findings in the southern part of the subtropics, where carpet grass pastures predominate, but it is expected that the principles and responses would be of a similar nature in cattle in more northerly areas of the subtropics.

Cattle under conditions of low productivity

During winter, cattle at best maintain live weight but generally lose weight; up to 50 g/d for young Hereford stock. Samples taken from grazing stock indicate low rumen ammonia concentration (6 to 15 mg ammonia-N/L) and low concentrations of plasma urea (15-30 mg N/L).

Experiments eliciting response in cattle

(i) Urea + minerals As little as 15 g urea/d elicits increased feed intake and liveweight change in cattle when urea is sprayed onto the hay and fed to them in pens, with a supplement of 45 g/d of minerals, including sulphur and phosphorus (Hennessy 1984). Daily liveweight losses of 50 g/d became a gain of 260 g/d with urea-sprayed hay with feed intake increasing from 2.5 to 3.8 kg DM/head/day and rumen ammonia concentrations increasing from 7.5 to 54 mg N/L.

(ii) Formaldehyde-treated casein When casein was treated with formaldehyde, at the rate of 6 g/kg crude protein, only 3% of the N was degraded in nylon bags located in the rumen for 48 h. Feeding 280 g/d of the protected-casein to cattle in pens offered carpet grass hay increased feed intake from 2.8 to 3.4 kg DM/d, liveweight change from 100 to 600 g/d, rumen ammonia from 32 to 100 mg N/L and plasma urea from 21 to 75 mg N/L (D. W. Hennessy, unpublished).
Protein meals. Meals which contain 400 g/kg DM of protein, of which at least half escapes rumen degradation, have increased productivity of cattle in pens (Hennessy et al. 1983) and at grazing (Hennessy et al. 1981; Hennessy 1983). Feeding 600 g/d of the meal to cattle in pens increased their intake of hay from 2.9 to 3.7 kg DM/d, changed a liveweight loss of 35 g/d to a gain of 425 g/d, increased rumen ammonia from 15 to 70 mg N/L and plasma urea from 22 to 88 mg N/L (Hennessy et al. 1983).

Discussion

The low productivity of cattle on native pastures in the sub-tropics is due to losses of weight and body condition during the winter when the pastures have matured and are dry. Corresponding with their low body condition, cattle have low concentrations of ammonia in rumen fluid and urea in plasma.

The limitation to growth and productivity is unquestionably nitrogen; irrespective of whether the added nitrogen is totally rumen soluble, partially soluble in the rumen or almost un-degraded in the rumen. But whatever the characteristic of the N source, the concentration of ammonia in rumen fluid is raised by N additions which presumably allows a build up in cellulolytic bacteria and a fully functional biomass, thereby increasing plant degradation and allowing increased forage intakes by cattle (see paper by Hogan; this review).

Protected protein (i.e. formaldehyde-treated casein) seems to offer an advantage over rumen-soluble urea on equivalent N-intake basis in terms of higher growth rates but not in terms of higher feed intakes. This suggests that protected casein may provide specific growth-limiting amino acids for digestion and absorption in the intestine that increase the efficiency of use of ME intake (see paper by Egan; this review).

Protein meals contain both rumen-soluble and non-degradable protein. Hence; the meals provide sources of ammonia directly to the rumen, and indirectly, through absorbed amino acids and recycling. Since growth, but not feed intake, is often higher in cattle given protein meals than those on urea-alone, these features suggest that the proteins in meals, in common with protected protein, may also provide specific growth-limiting amino acids.

CONDITIONS INFLUENCING A NEED FOR NITROGEN SUPPLEMENTATION OF CATTLE GRAZING SUB-HUMID TROPICAL PASTURES

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Beef cattle are managed under an extensive system in the sub-humid tropics of Australia. The growth of these cattle is characterised by a period of rapid growth followed by liveweight maintenance and then liveweight loss. The mean annual liveweight gain is determined by the length and intensity of the wet season and the incidence of rainfall in the dry season. This governs the green feed available and McCown (1981) has shown that the length of the green season can be relatively constant between years in some areas and extremely variable in others.

Pasture conditions

Most of the pastures used in beef production in the sub-humid tropics are unimproved. When soil moisture levels fall, grass growth slows and may cease. The resultant pasture then contains an increasing amount of stem in relation to leaf and the nitrogen (N) content falls. These factors contribute to a much lower
nutrient intake by grazing animals (Minson 1981). The low stocking rates on these pastures usually ensure that there is an abundance of dry, standing pasture after a normal season of growth. Occasionally, pasture may be in short supply due to abnormally low wet-season rainfall. In this case, a different management strategy would be adopted using supplements to make up for the shortage of pasture feed. This paper is concerned with the situation where there is an abundance of dry standing pasture.

**Animal requirements**

Tropically adapted (Bos indicus cross) cattle have several mechanisms which allow them to cope with periods of nutritional deprivation. Their lower basal metabolism compared with unadapted cattle means that energy requirements for maintenance are lower (Frisch and Vercoe 1977). There is also some indication that certain aspects of N metabolism may also be adapted (R. A. Hunter pers. comm). Thus the generally acceptable nutrient requirements tables (e.g. ARC 1980) may give requirements which are higher than necessary for the cattle which are grazed in the tropics. Because beef cattle are usually managed in an extensive, low-input system, periods of liveweight loss are acceptable. In years with a prolonged dry season, large numbers of cattle may require feeding to ensure survival. The usual target animals are young, growing cattle and pregnant and lactating cows because their nutrient requirements are higher than older or non-productive stock. The aim of feeding in the sub-humid tropics is to allow survival of the animal to the next wet season when compensatory gains ensure that much of the weight lost is recovered quite rapidly. However, high beef prices encourage graziers to have a more productive herd. Under these conditions, the aim of supplementary feeding is to increase weaning rates and reduce the time taken to market cattle.

**Indications of a need for nitrogen**

Winks et al. (1979) have shown that faecal N concentration is a useful indicator of when an animal will respond to supplementary rumen degradable N (RDN). Other workers have indicated that a dietary N content of more than 1% is necessary for liveweight gain (Siebert and Hunter 1977). Rumen ammonia N levels also indicate that RDN is limiting production during the dry season (Playne and Kennedy 1976).

In pen studies supplemental RDN has been shown to stimulate intake of pasture hay and reduce liveweight losses (Lindsay et al. 1982). Similarly, grazing studies have found that frequent consumption of RDN will reduce liveweight losses or encourage a small gain (Winks et al. 1979). However, productivity remains low.

The role of protected protein (URDN) has been investigated. Formaldehyde (F) casein increased liveweight gain above that of the RDN supplement but no further increase in roughage intake was recorded (Lindsay and Loxton 1981). Further experimentation with protein meals showed that a mixture of fish meal, meat and bone meal and F cottonseed meal (in the ratio 1: 1:8) when added to an RDN supplement increased roughage intake by 31% and changed a liveweight loss of 0.31 kg/d into a gain of 0.75 kg/d (Lindsay et al. 1982). Pregnant cows were used in this work and subsequent studies have shown that similar responses are possible with young, growing cattle (Lindsay et al. 1984).

**Mode of action of nitrogen supplements**

The dry, matured pasture is low in N and high in structural fibre. Supplemental RDN is available directly in the rumen and the ammonia released
Animal Production in Australia Vol. 15

stimulates microbial growth which allows a more rapid fermentation of the pasture. When a source of UDN such as F casein is fed, a liveweight response occurs following an increased uptake of amino acids. Protein meals may act in several ways. There may be a slow release of N in the rumen which will have a similar effect to frequent feeding of RDN. The carbohydrate fraction in the protein meal may also contribute to the glucose economy of the animal. MacRae and Lobley (1982) postulated that large quantities of acetate produced from roughage feeds may be utilised more efficiently if more reduced-coenzymes are available. Such a source may be the amino acids liberated in the small intestines from protected proteins.

When requirements for RDN and UDN are met, the limiting factor in production remains as ME intake. A recent study (J. A. Lindsay, unpublished data) found that liveweight responses could be increased by 43% when alkali-treated, whole sorghum was added to a supplement containing liberal amounts of RDN and UDN.

Conclusions

The mean annual liveweight gains of cattle grazing unimproved pastures in the sub-humid tropics are dependent upon the duration of the period of green feed. The provision of N supplements during the dry season will increase survival of cattle from year to year. A supplement of RDN will reduce liveweight loss or induce a small liveweight gain by increasing the intake of the low N, low digestibility pasture. When RDN and UDN are fed together the liveweight response is much higher because more pasture is eaten and more nutrients are available both from the extra pasture digested and the supplement. A further increase in productivity is possible when an energy supplement is included which does not reduce cellulolytic fermentation nor therefore reduce pasture intake.

REVIEW SUMMARY

The primary supply of protein to the ruminant is from the outflow of microbial protein from the rumen with, in general, secondary contributions from unfermented dietary protein and secretions of endogenous proteins. For temperate pastures, with DOM:CP values between 4 and 9, 64% of the dietary protein is degraded in the rumen, allowing sufficient rumen ammonia for microbial protein production which is related to the intake and fermentation of DOM. However, for matured temperate pastures, and many tropical pastures, the DOM:CP ratio is greater than 9 and supplementary N is required. Whilst sheep and cattle on such diets can expect increases of from 25 to 75% in total N input, from transfer of urea across the rumen wall, in saliva and from sloughed epithelial cells, such contribution only helps to maintain a viable microbial population in the rumen. It is unlikely that recycling of urea N would support a population capable of supplying enough energy and protein for production. Consequently the supply of protein reaching the intestine for example in sheep on low N roughages is below 6 g of digestible protein/MJ DE and it would appear that in these cases specific amino acids limit intake and Nretention. Only non-ruminally degradable protein, or abomasal infusion of the specific amino acids, removed the constraint to appetite and therefore production. Grazing studies in Northern Victoria, New South Wales and North Queensland indicate that when these basic principles are applied, much of the constraint to production imposed by the low N content of crop stubbles, or pasture, can be removed and a moderate growth achieved.

REFERENCES
