RECENT ADVANCES IN THE FEEDING OF BYPASS PROTEIN MEALS FOR GROWTH AND WOOL PRODUCTION

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I. INTRODUCTION

Ruminant animals have evolved with an ability to utilize low protein, high cellulose diets for maintenance. It is therefore perhaps not surprising that supplementation is often necessary to achieve the highest levels of productivity. In ruminant animals, the protein requirements for maintenance can usually be met by amino acids leaving the rumen in microbial cells. Because the amino acids normally considered to be essential for non ruminants can be synthesised by micro-organisms in the rumen from non-protein nitrogen (NPN) sources, ruminant animals require very little true protein in the diet for maintenance. However, in growing, pregnant or lactating animals, the requirement for amino acids often exceeds the supply from rumen microbial sources. In order to achieve high levels of productivity, it may therefore be necessary to supply dietary protein in forms which are non-degradable in the rumen (i.e. "bypass protein') but digestible and available for absorption from the small intestine. This requirement for true protein is relatively small and when the digestible protein and energy nutrients are correctly balanced, ruminant animals can be highly productive and have feed conversion ratios (FCR) of less than 3.5:1 on feeds containing less than 10% true protein in the diet whereas pigs and poultry require more than 15% true protein in the diet for optimal feed conversion ratios (Leng, Kempton & Nolan 1977).

The primary effect of increasing the protein supply to the duodenum is to-increase the level of voluntary feed intake (Egan 1965; Preston 1972; Ørskov, Frazer & Pirie 1973; Kempton & Leng 1978). It appears that voluntary feed intake is dependent upon the balance between digestible protein and energy nutrients (the optimal value is in the range 9-12 g digestible crude protein/MJ ME (Egan 1977)). Intakes of low quality roughage diets have been increased up to 60% by supplementing the diet with bypass protein (see Egan 1965; Kempton & Leng 1978; D.W. Hennessey, unpub. obs.). A particularly noteworthy feature of this intake response is that it can occur on low digestibility roughages which traditionally have been considered to limit feed intake by "rumen fill".

II. STRATEGY FOR PROTEIN SUPPLEMENTATION

In considering how to meet the N requirements of ruminant animals in practice, the following strategy can be adopted:

1. *Maximize the availability of microbial protein from the rumen* (i.e. maximize the rate of microbial protein outflow per dollar of feed). Usually this will mean attempting to maximize the use of cheaper non-protein nitrogen (NPN) forms and minimizing the use of more expensive true protein. Consideration must be given to the availability of ammonia (and other nutrients), the form and availability of fermentable energy substrates and the rate of rumen turnover.

2. *Estimate the quantities of protein (and hence amino acids) made available by the rumen microbes and undigested dietary protein.*

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leaving the rumen and to compare this with the amino acid requirements for *the desired level* of *production.*

3. If there is a deficit, *augment the amino acid supply by providing an appropriate amount* of *a dietary supplement containing protein in forms that* are *largely non-degradable in the rumen but available in the small intestine* (i.e. a "bypass protein").

These factors will now be considered in more detail.

III. MICROBIAL PROTEIN SYNTHESIS

Rumen micro-organisms require a source of substrate (energy), nitrogen (peptides, amino acids or ammonia) and also other nutrients (minerals and vitamins). The N requirements of rumen micro-organisms can be supplied almost entirely in the form of ammonia. However there are persistent suggestions than the maximum efficiency of protein synthesis can be achieved only if there are peptides and amino acids present in sufficient concentrations in the rumen (Wright 1967; Hume 1970; Maeng, Van Nevel & Baldwin 1976). The peptides and amino acids will generally be supplied by the rumen-degradable portion of a protein supplement. However, if the protein is virtually non-degradable in the rumen then a deficiency of ammonia in particular (but possibly also peptides and amino acids) might occur.

Ammonia requirements for the rumen microbes

The balance between the rate of ammonia production from dietary and endogenous compounds and its utilization in cell synthesis or absorption determines the concentration of ammonia in the rumen fluid. The concentration has therefore been considered as a practical indicator of the adequacy of ammonia supply for rumen microbial synthesis under different conditions. Various workers have put a figure on the concentration of rumen ammonia below which micro-organisms may be unable to obtain adequate amounts of ammonia for efficient cell growth. The rumen ammonia concentration most often quoted as being optimal is about 5 millimolar (Satter & Slyter 1974). However, there are indications that microbial activity may not be adversely affected when concentrations fall to much lower levels. In studies with grazing cattle at Gayndah, Mr. Alan Foster (personal communication) did not obtain responses to supplements supplying ammonia even when rumen ammonia concentrations were below 1 mM. As Buttery (1977) points out, the enzymes that are likely to initiate ammonia fixation by micro-organisms all have high affinities for ammonia, and micro-organisms also probably have the ability to concentrate ammonia. Taken together these two points suggest that the ammonia requirements of micro-organisms can probably usually be supplied at relatively low ammonia concentrations. Nevertheless, when Hume, Moir & Somers (1970) fed sheep diets based on purified ingredients, they observed that the maximum flow of protein from the rumen did not occur until rumen ammonia concentrations reached 9 mM. Similarly high concentrations were apparently found to be necessary to achieve maximal protein synthesis in studies in the U.K. with lambs fed rolled barley (Ørskov, Frazer & McDonald 1972) and in sheep fed a high energy, low N diet (Okorie, Buttery & Lewis 1977). In contrast to the studies with cattle at Gayndah, the studies in which the higher rumen ammonia concentrations were optimal were with animals given semi-synthetic rations with high levels of rapidly fermentable substrate. Such diets support different populations of bacteria, which

may have different abilities to concentrate ammonia as compared with those bacteria which grow on cellulolytic (roughage)-type diets. The rate of ammonia assimilation, in addition to the ultimate ammonia concentrating ability of the bacteria may also be important. Thus the effect of the diet on the type of microbial population present and the rate of rumen turnover may both be factors that can alter the concentration of ammonia which is necessary for optimal cell synthesis in the rumen. There is probably therefore no critical ammonia concentration in rumen fluid that is applicable under all conditions. For diets based on gelatinized starch (e.g. Starea) and rolled or crushed grains, there have been suggestions that ammonia concentrations in excess of 50 mM were necessary for optimal microbial synthesis (Bartley & Deyoe 1977). Much lower values (5 mM) are probably adequate for animals given roughage based diets and for animals at pasture.

At the present stage of knowledge it seems sensible to aim at rumen ammonia concentrations of at least 5 mM. Excess ammonia appears to have little adverse effect on rumen micro-organisms (Smith 1975) and at these levels, its absorption in the blood-stream is unlikely to adversely affect the animal. Much higher levels (> 20 mM) would however be wasteful and could also lead to ammonia toxicity.

In addition to N and available energy, a variety of nutrients could theoretically limit rumen microbial production. Sulphur, cobalt, and selenium deficiencies are of most practical significance and generally these can be avoided by the strategic use of crop fertilizers, licks, inclusion of mineral mixtures during feed compounding, or by rumen "bullets".

Maximizing microbial protein availability

The following have been associated with increased availability of microbial protein:

(i) rapid rumen through-put. This may lead to proliferation of more efficient species of micro-organisms (Sutherland 1976), reduced energy costs of maintenance (Stouthamer & Bettenhaussen 1973), reduced turnover and lysis within the rumen, and lower densities of protozoa (Leng 1976) which form part of the rumen biomass and utilize energy but produce cells that do not become available directly to the animal.

(ii) high molar ratios of propionate:acetate. High molar ratios of propionate (Jackson, Rook & Towers 1971) have been associated with high microbial cell yields. Absorbed propionate may also be an alternative to protein as a glucogenic substrate.

(iii) low levels of methane production. Loss of gaseous methane represents a loss of energy to the animal. However, recent studies suggest that methane may be produced, under certains conditions, by a secondary fermentation process in which bacteria utilize VFA as a source of energy. Under some conditions, the effect of the secondary fermentation may be beneficial in supplying extra microbial protein relative to energy (VFA) (Rowe, Nolan, Loughnan & Leng '1978).

IV. ESTIMATION OF THE MICROBIAL AMINO ACID SUPPLY

The amino acids supplied by the rumen system, calculated from published studies, are of the order of 3 g N/100 g OM fermented in the rumen, or 1.1 g N/MJ ME. However, these are only average values from a number of published studies. A large number of different efficiencies have been obtained in individual experimental studies and the reasons are only partly understood as discussed above.

Ørskov (1970) and Egan & Walker (1975) calculated, on the basis of average values for rumen microbial synthesis, that the microbial protein supply would be inadequate to meet the requirements for growth of lambs and young cattle; and inadequate for the needs of late pregnancy and for potential lactation. In general, an increase of 25-50% in the efficiency of microbial synthesis would have been needed to allow these requirements to be met solely from rumen microbial sources.

V. MEETING THE PROTEIN DEFICIT

Having calculated the animal's amino acid requirement for a given level of production (Hutton & Annison 1972; Chalupa 1976) and the amount of amino acids absorbed and retained, it is then possible to calculate the deficit. To achieve the desired level of production, it will then be necessary to provide extra dietary protein in a form which is relatively non-degradable in the rumen, but digestible in the small intestine.

If the preferred value of Egan & Walker (1975) for likely microbial protein supply is taken as a guide--i.e. 7 g microbial true protein digested in the small intestine/MJ ME--the extent of the overall deficit can be roughly calculated for producing animals. In lactating cows and growing lambs, the optimum ratio of absorbed nutrients has been calculated at between 10-15 g crude protein/MJ ME (see Preston 1976; Kempton, Nolan & Leng 1978) or about 8-12 g digestible true protein/MJ ME. It is therefore likely to be necessary to augment the supply of amino acids from microbial protein with 1-5 g non-degradable dietary true protein/MJ ME in order to balance the supply of absorbed nutrients. The actual dietary requirement will exceed this calculated value because proteins that bypass the rumen are not likely to be wholly absorbed in the small intestine, nor completely retained in the body.

Composition of absorbed protein

The above considerations take no account of the amino acid spectrum of the digested protein or the requirements for individual amino acids. The intake and growth response to non-degradable dietary proteins may result from correction of a deficiency of one or more amino acids. The spectrum of amino acids in microbial protein as compared with that of ruminant tissues suggests that methionine, lysine, histidine, threonine, and arginine are the most likely amino acids to limit growth (Hutton & Annison 1972; Chalupa 1976).

If supplementation strategies based on single amino acids or mixtures of amino acids are to be employed, it will be critical to maintain an appropriate balance of absorbed amino acids. For instance, synthesis of keratin requires a balanced supply of amino acids to

support maximum wool growth since:-

(i) Methionine or cyst(e)ine alone do not increase wool growth to the same extent as a composite amino acid supplement, e.g. casein (Gillespie, Reis & Schinckel 1964).

(ii) The supply of S-amino acids to the follicle frequently limits wool growth rate (Reis & Schinckel 1963) and provison of 0.5 - 2.0 g L cyst(e)ine or equimolar amounts of DL-methionine can increase wool growth by as much as 100% (Reis 1967). Provision of S-amino acids above these levels can depress wool growth, although the inhibitory effect varies with the particular diet (Reis, Tunks & Downes 1973).

(iii) Abomasal infusion of a lysine deficient protein (zein) will reduce wool growth. The effect was largely reversed by the addition of lysine to the infused mixture (Reis & Colebrook 1972).

Similarly, Dove, Pearce & Tribe (1977) have shown in lambs infused per abomasum with milk that deviation from an optimum essential amino acid/total nitrogen (EAA/TN) ratio of 3.2 severely reduced liveweight gains. Furthermore, the dietary supply of amino acids is used most efficiently when EAA and non-EAA are present in approximately equal proportions.

For practical purposes therefore, supplementation with the least expensive protein source of high quality (i.e. high TN content, low rumen degradability, high digestibility in the small intestine with an optimum EAA/TN ratio) should realize the best margins between supplemented and unsupplemented animals.

VI. FORMULATION OF DIETARY PROTEIN SUPPLEMENTS

The foregoing is a basis that allows the nutritionist to consider whether:

a) the total amino acid absorption (from microbial and dietary sources) is adequate to meet the requirements for the desired level of production, and

b) the individual amino acids are in optimal proportions.

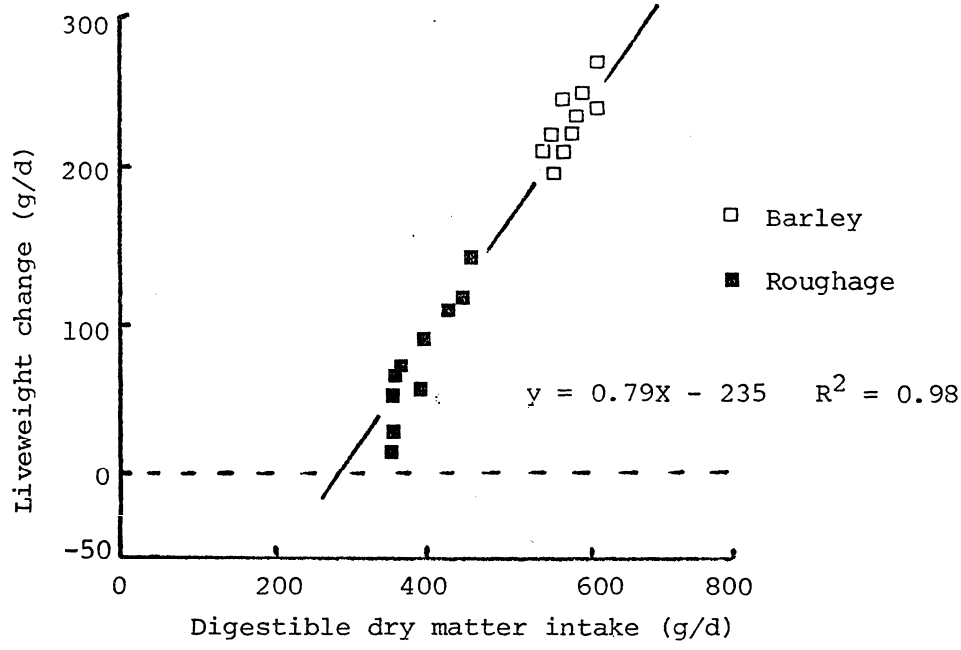
The proteins in most naturally occurring feedstuffs are at least partially non-degradable in the rumen, and the protein which passes through the rumen intact goes towards meeting any amino acid deficit. A knowledge of the rumen degradability of the available protein sources and of those protein's capacity to augment the supply of the potentially limiting essential amino acids is needed when deciding what supplements to use. Considerable information on the degradability of various high-protein ingredients is currently being obtained by a number of different approaches (e.g. in *vitro* solubility in mineral buffers, rate of disappearance from dacron bags suspended in the rumen, $^{15}NH_3$ production rates). The amino acid composition of protein sources with established ability to act as "bypass" sources can be determined by standard laboratory analyses or assessed according to their ability to support growth in the protozoan *Tetrahymena pyriformis* , or in rats, chickens

or ruminant animals themselves.

VII. EFFECTS OF BYPASS PROTEIN ON EFFICIENCY OF FEED UTILIZATION

Supplementation of low protein feeds based on cereal (starch), molasses (sugar) or roughage (cellulose) with a form of bypass protein increases feed intake and improves the FCR (kg feed intake/kg gain). Lambs that were losing weight on unsupplemented roughage diets had FCRs of 22:1 when supplemented with NPN, and 6:1 when supplemented with NPN plus a bypass protein. Similarly, in lambs on barley diets, supplementation with fish meal reduced the FCR from 6:1 to 2:1 (Ørskov, Fraser, McDonald & Smart 1974).

FCR is more difficult to interpret in ruminants as it is affected by the digestibility of the diet and the level of feed intake relative to maintenance. It is informative to combine data for lambs given roughage based diets (Kempton & Leng 1978) and barley based diets (Ørskov et al. 1974) supplemented with NPN and bypass proteins. The relation-between digestible dry matter intake (DDMI; g/d) and liveweight gain(g/d) is given below.



It was apparent that even though DDMI and growth rates were higher in the barley fed lambs, the efficiency of utilisation of DDM above maintenance of 79% was common to both diets (i.e. a FCR of 1.3:1). It would appear therefore that liveweight gain depends largely on the total intake of digestible nutrients rather than the efficiency of utilisation of digested nutrients.

VIII. GRAZING TRIALS - RESPONSES TO SUPPLEMENTATION OF LOW PROTEIN DIETS

Responses in both feed intake and liveweight to supplementation of low protein diets with NPN and bypass proteins have been repeatedly demonstrated in pen trials with both growing lambs and weaner cattle.

Bypass proteins have also been included in winter supplementary feeding strategies for grazing animals.

(i) R. Williams; this laboratory. Weaner cattle grazing mature standing pastures on the New England Tableland were supplemented with either urea-molasses or meat meal-dried molasses. Intakes of 150 g DM (22% urea N) urea-molasses had no significant effect on liveweight change, whereas intake of meat meal-molasses (up to 1.7 kg/d) stimulated liveweight gain up to 1.4 kg/d. An average 100 g of meat meal or soyabean meal promoted 75 g gain. However, only 26-40% of the animals consumed the meat meal-molasses whereas 95% consumed the urea-molasses.

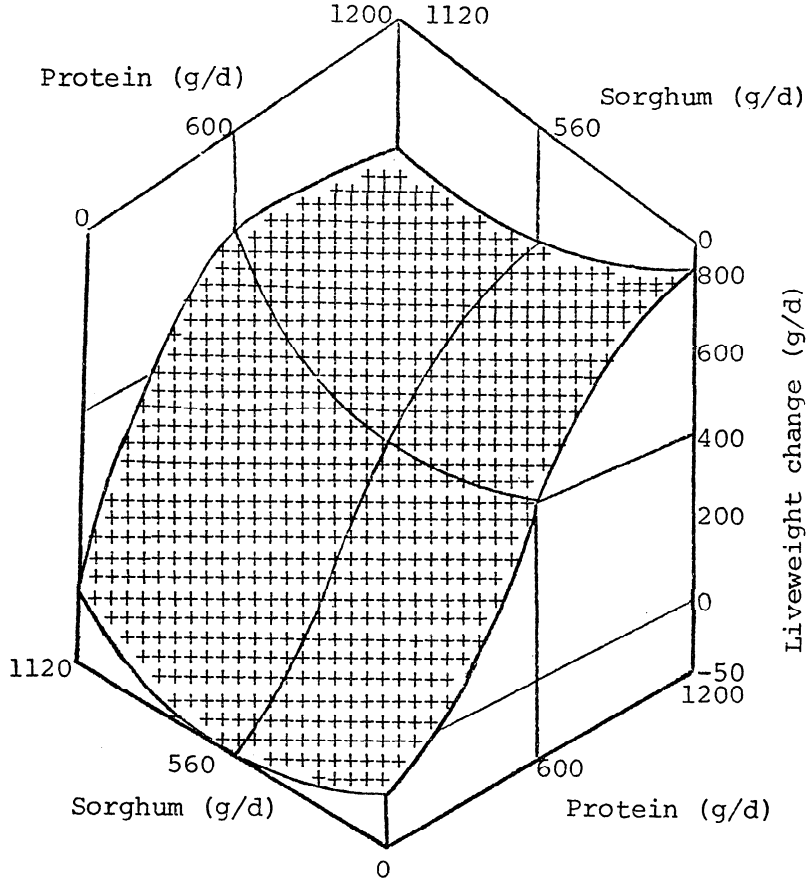
(ii) D. Llewelyn; DPI, Queensland. Pregnant heifers grazing low quality native pastures. in Southern Queensland, meat meal-molasses reduced the rate of liveweight loss over the winter period (by 260 g/d). A urea-molasses supplement had been shown to have no effect under similar conditions. On average 1 kg liveweight was spared by 3.7 kg supplement. Only 18% of the animals consumed the meat meal-molasses compared with 92% consuming the urea-molasses supplement.

In the following year, '62% of the animals consumed the meat meal-molasses supplement after they were confined in a small paddock and offered the supplement for 7 days. In those animals that consumed the supplement the liveweight loss was reduced by 170 g/d.

(iii) A. Foster; DPI, Queensland. At Gayndah, cattle grazing native spear grass-dominant pastures were supplemented with fishmeal and given restricted access to *Leucaena leucacephala* (a tropical legume). The supplemented animals grew at 850 g/d over a period when animals usually lose weight.

(iv) D.W. Hennessy, Dept. of Agriculture, NSW. Weaner cattle grazing native carpet grass at Grafton, North Coast NSW, typically lose weight over the winter period. Supplements of urea molasses or cereal grain generally are not effective in reducing the weight loss. Weaner steers were given approx. 0.60 kg/d of either a high protein pellet (cottonseed meal, meat meal, fish meal; 80: 10: 10) or sorghum, Over a 110 day supplementation period, the protein supplemented animals gained weight at 400 g/d, the sorghum supplemented animals lost weight at 40 g/d and the controls lost weight at 60 g/d.

In pen studies that simulated the field study, similar weaner cattle were given free access to carpet grass hay (47% dry matter digestibility) supplemented with either the same protein pellet, or sorghum, or combinations of these. The results are given in the figure. Liveweight changes were from 40 g/day loss in the controls to 750 g/day gain in the animals supplemented with 1200 g/d of the pellets. By comparison, animals given sorghum continued to lose weight. Hay intake was increased by 12% in animals consuming protein pellets whereas in those receiving sorghum in the diet, hay intake was reduced by 19%.



(v) Falvey (1977). Cattle in the Northern Territory were given a meat meal supplement over a four year period. An advantage of 80 kg in liveweight was observed in supplemented cattle as compared with the controls.

Taken together these results indicate that the feeding of -protein meals can be beneficial for a wide area of Australia where seasonal dry periods occur. With strategic protein supplementation the annual decline in liveweight can be avoided provided there is available dry matter. Protein meal supplements (as distinct from supplements containing cereal grain or urea molasses) apparently stimulate intake of native pasture and allow greater productivity from these poor quality feeds (even if these feeds are only 47% digestible). The economic returns are likely to be greater than for many supplements which do not stimulate appetite as well as having feeding value.

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