DEVELOPING A PROTEIN FEEDING SYSTEM FOR RUMINANT ANIMALS IN AUSTRALIA

J.V. NOLAN* and J.L. CORBETT**

SUMMARY

Complexities in the protein nutrition of ruminants are outlined to explain why digestible crude protein does not describe adequately the protein value of feeds for ruminants nor predict satisfactorily their requirements for and responses to dietary protein and'non-protein nitrogen. An effective protein feeding system must recognize the requirements for energy as well as nitrogen in rumen microbial growth, and that the quantity and quality of protein actually absorbed by ruminants, a mix of microbial and dietary, can differ substantially from the supply in the feed. These criteria are met by a new system that is being developed by a Working Party of the Animal Production Committee for the Introduction of Nationally Uniform Feeding Standards for Livestock.

INTRODUCTION

In animal production systems dependent on hand-feeding it is important to specify and provide for protein requirements as precisely as possible because protein feeds are generally the most expensive components of rations. This need occurs in Australian ruminant livestock industries such as dairying and lot-feeding. In addition there are major problems in the protein nutrition of grazing animals that include:

- Identification of a primary protein deficiency in animals grazing poor quality feed such as tropical pastures during the dry season, Mediterranean-type pastures during summer, and native pastures on the Tablelands during winter.

- Might the protein deficiency be made good by a non-protein nitrogen (NPN) supplement such as urea, or is a protein feed required and if so of what type and how much?

- If the protein content of the feed is inadequate for cattle, is it also inadequate for sheep which are able to select the more nutritious parts of the herbage (Langlands and Holmes 1978)?

- Is it possible to specify a particular protein feed that would promote particular types of animal production such as wool growth?

Resolution of these and related problems requires detailed knowledge of the complexities in the protein nutrition of ruminants (Leng et *al.* 1977). Dietary protein is broken down by the microbial population in the rumen to an extent varying with the physical and chemical characteristics of the protein and the time it remains in that organ. Residence time in turn varies with the type and quantity of diet consumed, with the physiological state of the animal (e.g. pregnancy and lactation; Weston 1979) and with environmental conditions (e.g. low ambient temperature; Kennedy *et al.* 1976). The products of protein breakdown (peptides, amino acids, ammonia), and dietary and endogenous NPN, are utilized by the microorganisms for their own growth which is dependent also on the supply of substrates that supply energy and nutrients such as sulphur and

* Dept. of Biochemistry and Nutrition, University of New England, Armidale,, NSW, 2351.'
** CSIRO, Division of Animal Production, Armidale, NSW, 2350.

cobalt. Energy is provided by a variety of components of the diet and a particular feature of ruminant digestion that is so useful to man is that cellulose, which is unavailable to mammals because these lack cellulolytic enzymes, is fermented and used as a source of energy by bacteria; the steam-volatile fatty acids produced in the fermentation processes provide the host animal with a substantial part of its total energy gain from the diet. Experiments have shown that ruminants can survive and produce on protein-free feed using urea and ammonium salts as the sole sources of nitrogen (Virtanen 1966), but in general some dietary protein is required for higher production (Preston and Willis 1970; Ørskov *et al.* 1973). With feeds used in practice, some ruminal degradation of the protein these contain is an inevitable cost in the fermentation of cellulose and other materials that yields substances of direct use to the animal and thence products of value to man.

An effective protein system must therefore take account of the interactions in ruminal fermentation between the availability of energy as well as of nitrogenous materials for microbial growth, and recognize that the amino acids absorbed by the animal from its small intestine are substantially of microbial origin with a varying admixture derived directly from the diet. It must also take account of digestion and metabolism in the animal as a whole in relation to such matters as amino acid supply and feed intake, and parasitism.

Development of feeding systems in Australia

An Expert Panel on Australian Feedstuffs was established by the Animal Production Committee (APC) in 1974 and this Panel recommended that standards for livestock feeding in Australia should be based on a Metabolisable Energy System similar to that in use in Britain. Upon receipt of these recommendations the Standing Committee on Agriculture agreed to the establishment of a Working Party for Introduction of Nationally Uniform Feeding Standards for Livestock with the following terms of reference:

(a) to implement feeding systems for ruminants and poultry based on metabolizable energy (ME):

(b) to seek extension of these systems to pigs;

(c) to develop corresponding standards for protein; and

(d) to seek standards of analytical methods for feeds in connection with the above.

Progress reports of the Working Party and of its specialist Sub-Committees working to establish feeding standards for ruminants, for poultry, and for pigs, will be presented to the Biennial Conference of the Australian Society of Animal Production at Perth in August 1980. The Ruminants Sub-Committee discussed protein nutrition jointly with a number of those in Australia expert in this subject when it was agreed that the digestible crude protein system (DCP) had serious failings and that a new approach should be developed and adopted for practical use which would, unlike DCP, meet the criteria for an effective system that are outlined above.

Digestible crude protein (DCP)

DCP is simply the difference between the intake of crude protein (N x 6.25) and the CP excreted in the corresponding faeces. Although this concept has use in the feeding of non-ruminant animals it is inadequate and has low predictive value for ruminants. It does not distinguish NPN in feed from protein and other nitrogenous materials, nor between proteins having different chemical and physico-chemical characteristics. It takes no account of the fact that the crude protein in faeces is predominantly microbial including some arising from fermentation in the hind gut (caecum), not undigested dietary material, nor of the fact that the type and quantity of the protein available to the animal for absorption often differs substantially from feed CP. At one extreme, the protein reaching the duodenum may be virtually all microbial; this occurs when the animal's diet is low in true protein, or the protein is highly degradable, but the supply of fermentable substrates yields sufficient energy for utilization of the available NPN. At the other extreme, when the dietary protein is 'protected' chemically or physically from attack by microbial enzymes most of it may pass intact to the small intestines, and is often termed 'by-pass protein*. In this instance the continuance of microbial activity at a level sufficient to maintain active fermentation in the rumen contents, their passage from that organ and thence maintenance of intake, will be heavily dependent on N recycled in the animal's body to the rumen via saliva and across the rumen wall. This supply might be insufficient so that although the ration appeared extravagant when judged on DCP content, additional 'DCP' in the form of NPN would then have to be included to sustain the animal's feed intake and production. In the former instance, low or readily degradable feed protein, the quantity of protein entering the duodenum will be greater than the quantity Of CP in the feed if there is an insufficiency of dietary NPN relative to the energy supply. Weston and Hogan (1973) reported that this gain, from utilization of recycled N, occurs with forage diets containing less than about 27g CP per 100 g digestible organic matter (DOM). At greater CP concentrations in DOM, flow to' the duodenum becomes less than intake because excess N, as ammonia, is absorbed by the animal and much is converted in its liver to urea and is excreted.

Thus DCP is truly a 'crude' description of the protein value of feeds. It bears only a tenuous relationship with the quantity of protein absorbed, and with its quality which will resemble that in the diet only when large amounts of the latter pass undegraded through the rumen. In Britain,, the Agricultural Research Council in the first edition of "The Nutrient Requirements of Farm Livestock: Ruminants" (ARC 1965) proposed a modified DCP system termed Available Protein, As described above the ingestion of feed results in the excretion in faeces of considerable quantities of microbial N products; these comprise the major part of the 'metabolic faecal nitrogen' (MFN) fraction which also includes endogenous secretions into the gut that are not re-absorbed and cellular detritus from the gut wall. The ARC discounted DCP by the quantity of MFN that the ingestion of the feed entails, taken'to be 5g per kg dry matter intake; to do this it had to express the MFN which was taken to have a biological value (BV) of 100, in terms of DCP that had some lower BV:

$$\text{Available protein (\%)} = \text{DCP (\%)} - 6.25\ \text{MFN}\ \left(\frac{100}{BV} - 1\right)$$

While BV is a useful measure of protein quality for non-ruminant animals (Evans. and Witty 1978) and is appropriate if applied to the protein, dietary and microbial, absorbed from the small intestines of ruminants, it is clearly of dubious validity to assign a BV to the dietary proteins apparently digested by the latter in their entire alimentary tract. In addition the Available Protein system does not take account of the close link between energy and protein and has been abandoned by the ARC in favour of a new system. The approach of Hogan and Weston (1974) includes some elements of the latter type of system; they reported that the quantity of CP entering the duodenum as a fraction (possibly greater than 100%) of dietary CP intake could be predicted from the ratio of DOM to CP in the feed.

New protein feeding systems

The new generation 'of protein feeding systems bring together the results from work by. nutritionists, biochemists, bacteriologists, and digestive physiologists. The first schemes to be published included those of Preston and Willis (1970), Burroughs *et al.* (1972), Miller (1973), Egan and Walker (1975), Burroughs *et al.* (1975) and Satter and Roffler (1975). The scheme described by Roy et *al.* (1977) foreshadows its adoption by the ARC in its new edition of 'Nutrient Requirements of Farm Livestock: Ruminants' now in press; the one described by Verité *et al.* (1979) is now adopted in France. These systems vary in matters of detail; that of Roy *et al.* (1977) described here indicates the approach common in all.

This system envisages a demand for amino acids by the animal's tissues that must be met by absorption of amino acids from the small intestine. These amino acids are provided from two main exogenous sources, namely microbial protein and unfermented feed protein. There are thus three general considerations:

1. The quantity of amino acids that has to be absorbed to meet the body's needs for maintenance, defined as endogenous urinary N losses and the N in hair, wool and from the skin, plus the needs for the'required production (growth, milk and reproduction);

2. The supply to 'the small intestine and thence to the body of microbial amino acids; calculated from a knowledge of the ME intake commensurate with the required level of production;

and 3. The quantity of amino acids available from unfermented dietary protein flowing into the small intestine.

This scheme is a classic development but employs a number of simplifying assumptions involving use of a series of constant factors to quantify a series of metabolic processes that are dynamic and highly, interactive as discussed by Faichney *et al.* (1980). Thus the calculation . . of (2) above depends'on the assumptions that of total digestible . OM intake, a constant 65% is apparently digested in the rumen (ADOMR) and that per kg of ADOMR there is a net yield of (30 x 6.25) g of microbial 'protein. However, there is evidence that the ADOMR fraction is not a constant; Ulyatt and Egan (19.79) showed it varied directly with the digestibility of the feed OM and a similar relationship was found with grazed pasture herbages (Corbett 1980) where ADOMR varied from 41 to 75%

over a range in OM digestibility from 54 to 83%. Values reported for the efficiency of microbial synthesis also vary widely, from about 50 to 150% of the assumed 30g N per kg ADOMR. Some of this variation may be due to errors in the methods for estimating microbial production (Siddons *et al.* 1979), but much will be real reflecting factors such as variation in fractional outflow rates of digesta from the rumen; the more rapid this is, in general the greater will be the net microbial protein yield (Sutherland 1976). With grazing sheep, outflow rates were substantially greater than usually reported for sheep fed dry forages and yields were around 40g *N* per kg ADOMR (Corbett 1980); similar values for sheep given fresh pasture herbage were reported by Walker *et al.* (1975).

The 30g N per kg ADOMR in the new ARC scheme is the quantity of *N* that should be supplied to the microorganisms by degradable feed protein plus NPN, collectively termed rumen degradable *N* (RDN) or rumen degradable protein (RDP = RDN x 6.25). The quantities of RDN provided by the proteins in various feeds are described by listing these in classes with rumen degradabilities of <31% (e.g. dried sainfoin, which contain tannins that confer some natural 'protection' to its protein), 40% (e.g. fish meal), 60% (e.g. flaked maize, cooked soya bean meal) and 80% (e.g. hay, silage, barley). The *RDN* supplied by a ration is the sum of the quantity of protein in each component feed multiplied by its assumed degradability; the remainder is termed undegraded dietary protein (UDP). The assigned degradability values are only approximations to the true values which can vary among feeds of the same type from different sources if there has been variation in processing and thence in effects on their chemical and physical characteristics, and the protein in a single sample of a feed will vary in degradability with its residence time in the rumen as discussed above.

When the digestible OM in a diet is expressed as ME, the requirement of RDN for the microorganisms is taken to be 1.25g per MJ of ME, or 7.8g RDP per MJ. If the diet supplies less RDN, no allowance is made for N recycling and the additional amount that has to be supplied as urea is calculated on the assumption that its net efficiency of conversion to microbial N is 80%. The (30g N x6.25) per kg ADOMR, or.7.8 g CP per MJ of ME, is also the net quantity of microbial crude protein that becomes available for digestion by the animal, It is recognised that part of the microbial CP, taken to be 20%, is nucleic acids of little protein value to the animal. The remaining 80% is assumed to be 70% digestible in the small intestines; the resulting net 56% of microbial protein absorbed as amino acids is then assumed to be used with 75% efficiency by the animal to meet its needs for maintenance and production as defined in (1) above. The supply of amino acids of microbial origin to the animal it will now be seen is calculated in relation to dietary energy content as (7.8 x 0.8 x 0.7 x 0.75 = 3.3g per MJ of ME). If this supply is less than the animal's defined need the ration must be reformulated to include additional UDP, also taken to be 70% digestible and used with 75% efficiency. Clearly the outcome of these calculations to match the animal's feed intake with its requirements will be incorrect if any one of the factors used is erroneous, and even quite small inaccuracies in these can substantially alter the estimate of additional UDP required. There. does appear to be less real variation around the 70% digestibility factor than occurs, forexample, with degradabilities and microbial yields. Variation in the profile of amino acids absorbed is at present ignored, and the N in the total is unlikely to be used.

always with 75% efficiency; for example, Hogan et *al*. (1980) estimated efficiency of use for wool growth was only about 12%.

A protein system for Australia'

The new approaches provide a sound conceptual basis for prediction and evaluation of nitrogen requirements. Roy *et al*. (1977) stated/It is fully recognized that the calculations involved in the proposed system necessitate the use of average values for factors; for which the supporting evidence is sometimes meagre and often very variable. Moreover, there are insufficient data to permit statements of requirements to be made in terms of individual amino acids, although data for essential amino acids could be incorporated into the system as they become available. The proposed system should be regarded, therefore, as a framework for future research'efforts and as a means of focussing attention on those factors for which additional data are required".

The Ruminants Sub-Committee of the APC Working Party has considered the approaches and conclusions of Roy *et al*. (1977) and proceeded from that basis. To overcome the criticisms which can be levelled at the use of constants in 'the ARC scheme, it is evaluating. the dynamic model of rumen function developed for computer simulation purposes by Black *et al*. (1980). In this model, account is taken of the dynamic interactions in ruminant digestion and metabolism without recourse to constant factors. For its application, information is required on the quantity and quality of feed consumed, including definition of its physical and chemical properties that govern the rates and extent of breakdown of its components in the rumen, and their rates of flow from that organ. Predicted outputs from the rumen then have to be matched with the various needs of animals. The Ruminants Sub-Committee is establishing means for predicting the feed intake of animals,and is evaluating results from Australian studies on supplementation of grazing animals with protein feeds which indicate these feeds effect greater intake and production from low quality forages. Another Sub-Committee (Chairman, Dr D.J. Minson) has responsibility for coordinating definition of methods for analysing feeds and evaluating them in such terms as their degradability. Some problems associated with estimating degradability are discussed by T.J. Kempton (these Proceedings)'.

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