Supplementation to Increase Growth Rates of Cattle in the Tropics-Protein or Energy

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Summary

Higher growth rates in cattle are required in many production systems in order for graziers to access premium markets. Supplementary feeding is just one option available to the grazier but it provides the flexibility of being able to react quickly to changing climatic or market situations. The question is what to feed, when and how much. The main options for significantly increasing growth rates are protein meals or "energy" sources such as cereal grains or molasses. Despite their quite different chemical compositions, calculations from feeding tables indicate that the supply of nutrients from the protein meal or energy source to the animal is closer than their compositional differences suggest. The estimatated metabolizable protein supply from cottonseed meal was only 6 1% higher than for barley (148 vs 92 g/kg DM) for growing steers despite a three-fold difference in crude protein content. Thus reference to supplements as protein or energy supplements is not appropriate. The comparison between protein meals and grains is hampered by the lack of good data from experiments in which both have been fed in parallel over a wide range of intakes. Cattle Iiveweight response data relating to the different supplements are considered separately, and a model of response is proposed for discussion and later testing under field conditions. This model suggests that the two supplement types have properties favouring their use at different points on the response surface. A major factor affecting the nature of the response curve is the impact of the supplement on intake of the basal diet, in particular on substitution. Possible differences between supplements in this regard are raised. Further comparative dose response field trials are required to allow appropriate economic analyses.

Introduction

Major changes have taken place in the nature of the beef industry over the last decade which have promoted changes in the whole approach to cattle and property management. These changes are most pronounced in the northern tropics of Australia. The emergence of lucrative markets in northern Asia which provide premiums for high quality product has been the major catalyst to change in the husbandry and nutrition of cattle. Furthermore, on the domestic scene there is an increasing awareness of the need to provide a consistent, high quality product in order to repel competition from the white meat industries. To meet these market requirements, it is well accepted that animals will have to reach the target weights at a younger age than has previously been the case when the export market revolved largely around supply of manufacturing beef to the United States, and this will require increases in annual growth rates. Feedlotting of cattle has increased dramatically as a strategy to meet the current market specifications, but there is also an increasing role for grass-finishing of cattle for these higher priced markets.

Supplementation is just one of a number of options available for increasing growth rates of cattle; others include the use of improved pastures and forage crops. However, it is an important option because it provides the producer with a tool to respond to adverse seasonal conditions or new market opportunities at short notice,. The question is then one of what, how much and when to feed in order to most profitably achieve the stated goals. The main supplement options currently available to the northern producer are protein meals or "energy"-based supplements, with the energy content based on either starch (grains) or soluble sugar (molasses). A discussion of these options for feeding is the subject of this paper.

Nutrient Supply from Supplements

It is inappropriate to use the term supplement for feed sources added to the basal ration, when the added feed source constitutes a large proportion of the diet, or when it depresses intake of the basal diet. Similarly, for reasons outlined below, reference to protein or energy supplements, based on their respective chemical compositions, is also inappropriate and leads to confusion with advisors, producers and scientists. However, for convenience and lack of apparent alternatives, these terms will continue to be used in the present discussion.

Protein supplements rarely exceed 50% crude protein (CP) meaning that there is a considerable carbohydrate component which acts as an energy source for rumen microbes to utilise. Similarly, the ability of rumen microbes to utilise the energy component of energy supplements, eg., barley grain, to synthesise microbial protein means that this groups of supplements provide considerable quantities of protein to the animal. Thus both supplement types provide both protein and energy to ruminants. Calculations based on AFRC (1992) show that cottonseed meal provides more metabolizable protein /kilogram of dry matter (DM) and a higher protein:energy (P/E) ratio than barley although the difference is considerably less than their chemical compositions would suggest (Table 1). Also, if the energy of the metabolizable protein (MP) is taken into account and subtracted from metabolizable energy (ME), then the P/E ratio expressed as g MP/MJ of non-protein ME is much higher for cottonseed meal.

The energy supplement, barley, provides quite considerable amounts of protein in the form of microbial protein but only if there is a source of effective rumen degradable nitrogen (ERDN). With tropical pastures or other low quality roughages this would be most improbable and urea, or some other ERDN source, should be used, probably at higher rates than are commonly employed (1% urea in grain; w/w). If ERDN requirements are not met, protein supply to the animal will be reduced and it is our belief that a limiting supply of this nutrient and other nutrients essential for microbial growth, eg., sulphur, have led to inefficient utilisation of energy supplements in some experiments. In the example in Table 1, if ERDN requirement is not met then the microbial CP (MCP) supply is 95 and 89 g MCP/kg DM at fractional outflow rate of 0.02 and 0.05 respectively, leading to a total MP supply of 70 and 71 g MP/kg DM respectively. This includes the digestible undegraded protein (DUP) contribution. These values contrast with values of 80 and 92 g MP/kg DM from Table 1. This, in association with lower P/E values, might in part contribute to the greater substitution effect of grain supplements, and the greater liveweight response to cottonseed meal seen in the collation of experiments detailed later. Cottonseed meal has ERDN in excess of microbial requirements so that with low quality diets it may stimulate intake as well as microbial protein production (see later).

It has been well established that grains differ quite markedly in the extent to which their protein and starch components are utilised in the rumen or in the total tract. In general, sorghum grain starch and protein is less digestible by cattle compared with barley or maize starch and protein, and much of this difference between grain sources derives from the lower digestibility of components of sorghum in the rumen (Waldo 1973; Spicer et *al.* 1986). This has implications for microbial protein synthesis with different grain sources. Spicer et al. (1986) showed that the amount of non-ammonia nitrogen reaching the abomasum of cattle was similar with barley- and sorghum-based diets but the percentage of bacterial nitrogen was much higher for the barley relative to the sorghum diets (72 vs 47%). In fact, the microbial protein yield was similar for sorghum, maize and barley in this study (ca. 32.3 g bacterial N/kg OM digested in rumen) but the amounts digested in the rumen differed for the differ-

Table 1 Estimated metabolizable protein (g) amd metabolizable energy (MJ) supply per kilogram of DM of a supplement of cottonseed meal or barley and the resultant protein/energy ratio of the end-products of digestion (AFRC 1992)

	Cottonseed meal		Barley	
Level of feeding.....	Maintenance	Growing steer	Maintenance	Growing steer
Fractional outflow rate (h^{-1})	0.02	0.05	0.02	0.05
Metabolizable energy (ME; MJ/kg DM)	11.1	11.1	12.8	12.8
Crude protein (CP; g/kg DM)	375	375	114	114
Digestible undegraded protein (DUP; g/kg DM)	51	92	9	14
Microbial CP (MCP; g/kg DM)[A]	79	88	111	123
Metabolizable CP				
(g/kg DM)= (0.6375 MCP + DUP)	101	148	80	92
(g/MJ ME)	9.1	13.3	6.2	7.2
(g/MJ non-protein ME)[B]	11.6	19.5	7.3	8.7

[A] assuming ERDN requirements are met, if not from supplement itself, then from a urea-based supplement. In the case of cottonseed meal ERDN supply is greater than microbial requirement but with barley it is less than microbial requirement and urea will have to be added at the levels of 7.0 and 14.8 g urea/kg DM at fractional outflow rates of 0.02 and 0.05 respectively.

[B] by subtracting the gross energy of MP from ME.

ent sources. Sorghum also has a high content of acid detergent indigestible nitrogen (ADIN) which is not available to the microbes or the animal.

Response to supplements

Protein meals

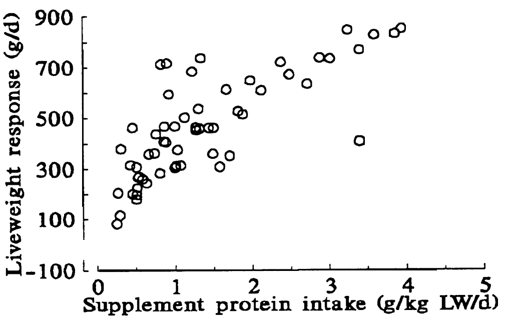
Protein supplements are now used extensively in the beef industry and the benefits in terms of improved animal performance are generally accepted. Despite this, there has until relatively recently been little effort to clearly define the response relationships for grazing animals upon which profitability analyses can be established. Consequently, low levels of feeding have generally been employed on the basis of low cost of feeding. However, the need to significantly increase growth rates of cattle has awakened a new interest in feeding higher amounts of supplement. There is also a greater interest in feeding supplement to cattle in all seasonal conditions through an awareness that if annual growth rates are to increase, animal performance will need to increase in both the wet and dry season.

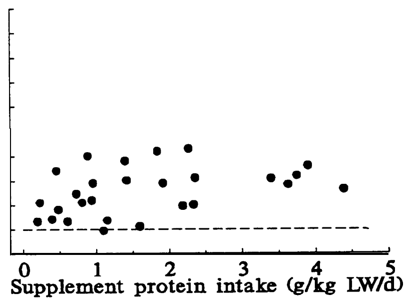
It is obvious that the response to protein supplementation is highly dependent on the quality of the basal diet. In a recent review, Poppi and McLennan (1995) examined the responses to protein meal supplementation for cattle with access to low quality diets, either grazed (eg., dry season pasture) or as roughage in pens, and to higher quality diets (eg., wet season pasture). Most data was extracted from experiments employing a dose response approach involving three or more levels of supplementation. This data is reproduced in the current paper showing the liveweight response (over unsupplemented control animals), with additional more recent data included (see Figures la, lb). Whilst a linear response relationship can be fitted to the data for low quality roughages where low to medium intakes of protein meal are fed, over the full range of intakes the response curve is obviously curvilinear, with a plateau reached at about 900 g/d response above the unsupplemented controls in the data shown (Figure la). This is consistent with the conclusions of Leng (1995) who fitted exponential equations relating liveweight performance and intake of cottonseed meal in various published data sets. Only very recently have the higher intakes of protein meal been examined under experimental conditions and, in most other studies included in Figure la, the curve had not reached plateau at the highest level of supplement intake. This has been a deficiency in previous work where the range of supplement intakes examined appears to have been determined on the basis of costs of feeding and the perceived lack of economic return from high levels of feeding.

The data included in Figure 1 have been used to estimate the conversion ratio of protein meal to additional liveweight gain (kg/kg). Where the response relationship between liveweight gain and intake of protein meal tended to be linear, the conversion ratio was estimated as the reciprocal of the slope of the regression line relating these parameters. In general, an intake of approximately 1.5 to 2.5 kg protein meal supplement was required for each additional kilogram of liveweight gain, representative of what could be expected to be a highly economic return from feeding. This relationship takes no account of the different protein content of the various protein meals represented, and the corresponding conversion ratios expressed as kg supplemental protein intake per kg additional liveweight gain ranged from 0.3 to 1.1. Whilst the conversion ratios are useful for predicting the likely response to supplement and the profitability of feeding under practical conditions, they overestimate the direct response from supplemental protein on the basis that intake of low quality roughages is often increased in the presence of protein supplementation (Hennessy and Williamson 1988; Leng 1990) and this contributes to the increased production.

Much higher conversion ratios were estimated when very high intakes of supplement were included,

Figure 1 Liveweight gain responses of animals (above unsupplemented controls) supplemented with increasing amounts of protein meal when given access to (a) low quality forage or (b) medium-high quality forage. Data collated from Hennessy *et al.* (1983), Smith and Warren (1986a,b), Irlbeck et al. (1989), Perdock and Leng (1990), Karges et al. (1992), Moss and Murray (1992), McLennan et al. (1993), Mbongo et al. (1994), Mbongo (1995), Dolberg and Finlayson (1995), J. Lindsay (pers. comm.) and McLennan and Poppi (unpubl. data). Adapted from Poppi and McLennan (1995).





such as was the case in the experiments of Dolberg and Finlayson (1995). The response curve over the range of intakes they used (0 to 4 kg/d cottonseed cake) was exponential and the conversion ratio (6.6) was determined on the response to feeding at the highest level of intake. The low conversion ratio at high intakes obviously reflects the fact that the response relationship follows the laws of diminishing returns, and at high intakes of protein meal there is only small increase in liveweight gain for each increment of protein feeding. This principle is illustrated in Figure 2 using some of the data from the experiments represented in Figure l(a).

With higher quality forages, the response relationship also appears to be curvilinear (see Figure l(b)) but with a maximum liveweight response of only about 0.3 kg/d above the control, reflecting the higher base growth rate of unsupplemented animals. It appears that this level of response can be achieved with relatively low intake of supplemental protein meal intake, and M. Bolam (pers. comm.) recorded an excellent conversion ratio of 1.1 kg fish meal per kg additional liveweight gain. At higher intakes of supplement, conversion ratios in excess of 10 were recorded.

So far the discussion has centred around the response to protein supplements but an important consideration for commercial cattle producers is knowing the maximum liveweight gain achieveable with different supplementation strategies. The data analysed in Figure 1 is also presented in Figure 3 as liveweight gain against supplement protein intake. It is interesting that the maximum growth rate irrespective of base production levels or intakes of supplement is about 1 kg/d. The exponential growth response curves derived by Leng (1995) for cattle supplemented with cottonseed meal also plateau at growth rates of 1 kg/d or less. It appears that some factor other than protein intake is limiting production at this point, perhaps a deficiency of energy to utilise the available protein (Ortigues *et al.* 1990) or a deficiency of specific limiting amino acids. This area deserves further attention.

Grain

Feedlotting of cattle in Australia has increased dramatically over the last decade in response to the increased demand from northern Asia for heavy carcases from younger cattle, and also to increased demand from the domestic market. Whilst short-term lot feeding is probably the most relaible means to reduce age at turn-off, it is not always the most profitable due to the high costs involved and the instability of feed costs and beef prices even during the course of the feeding operation. It is also associated with an environmental cost which is becoming increasingly scrutinised by governments and consumers. An alternative is to feed grain- (or molasses-) based rations in the paddock.

Coleman *et al* (1976) reported a curvilinear relationship between level of supplemental energy intake and rate of liveweight gain by cattle, indicating that the increase in the rate of gain diminished with increasing intake of supplemental energy. Taylor and Gulbransen (1990) and Rowe *et al.* (1994) reported similar trends. The data in Figure 4 illustrate the declining response to grain feeding when the high quality of the basal diet allows quite high growth rates from unsupplemented cattle, and also the declining response with increasing intake of grain. Nevertheless, in two experiments, grain feeding did promote liveweight gains well in excess of 1 kg/d. These higher growth rates with high intakes of grain are to be expected as the ration approaches the traditional high-grain feedlot ration.

Estimates of the conversion ratio of grain to additional liveweight gain ranging from 4 to 12 were deduced from the experiments of Tayler and Wilkinson (1972), Gulbransen (1976) and Rowe *et al.* (1994), but in the study of Taylor and Gulbransen (1990) in which mature Brahman crossbred steers were fed, the

Figure 2 Liveweight gain responses of cattle (above unsupplemented controls) supplemented with increasing amounts of protein meal. Data are from experiments listed in Figure 1 (a).

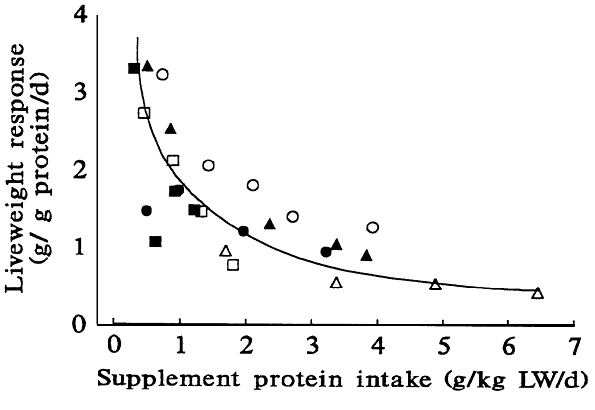
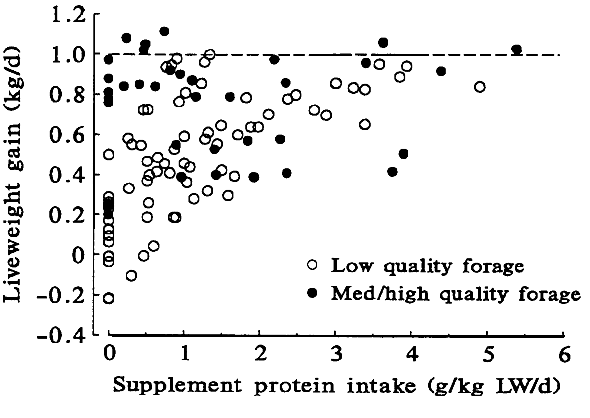


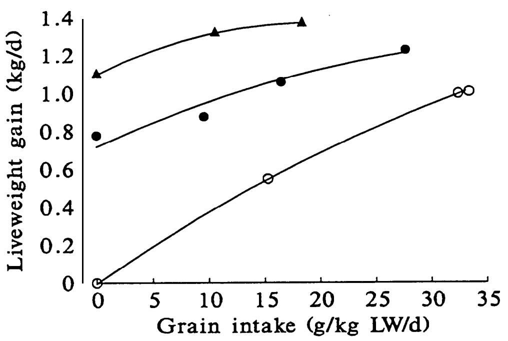
Figure 3 Liveweight gains of cattle receiving increasing amounts of protein meals and given access to either low quality forage or medium-high quality forage.



much higher value of 18 resulted. Age and size of the animal, quality of the basal diet and intake of grain all impinge on the conversion efficiency of grain to liveweight gain. Furthermore, the conversion ratios underestimate the true contribution of the grain as they fail to take into account the reduction in forage intake associated with increasing gram intake (see below). The other relevant point is that liveweight change underestimates the effects of grain feeding on carcase growth, as grain feeding is associated with reduced gut fill and increased dressing percentage (Tayler and Wilkinson 1972; Gulbransen 1976). Where possible, therefore, experiments should include measurements of carcase yield at the beginning and end of feeding. Gulbransen (1976) reported a conversion ratio of 12.3 kg grain/kg carcase gain, which compared favourably with that recorded for lot-fed cattle of the same size (Preston and Willis 1970).

In some field studies, growth rate of cattle have failed to exceed 1 kg/d and this has been attributed to the fact that grain intakes were not sufficiently high, although the grain was offered *ad libitum,* to achieve the higher growth rates (B. Gulbransen, unpubl. observations). A possible reason for the self-imposed limitation on grain intake by cattle may be the incidence of sub-clinical acidosis. If this is so, inclusion of the rumen modifier virginiamycin may be beneficial in elevating grain intakes by cattle and thus growth rates (Rowe and Zorrilla-Rios 1993). This warrants some investigation.

Figure 4 Liveweight gain of cattle receiving increasing intakes of grain in the diet. Data are collated from Gulbransen (1974, 1976b).



The discussion so far has concentrated on cereal grains as the energy supplement. However, molasses has long been used in the northern beef industry and has a marked price advantage over grains. Fortified with urea, protein meals and minerals, it is now becoming more widely used as a supplement for finishing cattle. Molasses and cereal grains give similar milk and liveweight responses when fed at the same DM intake (1.3: 1 .0 “as fed”; Cowan and Davison 1978; Gulbransen 1985). However, intakes of molasses tend to be lower than for grains, limiting the range of responses achievable. Although response surface data are limited, molasses appears to give a similar curvilinear pattern to grain.

Effects of Supplements on Intake

An earlier section has shown that, on the basis of theoretical supply of nutrients to the animal, some differences in cattle performance can be expected from feeding protein or energy supplements under practical conditions, but that these differences are likely to be much less than the differences in chemical composition would suggest. Whilst these calculations are useful to explain differences in response to the various supplements, they take no cognizance of the effect these supplements have on intake of the basal diet - the pasture. This is a critical factor affecting animal performance.

A well recognised and documented effect of grain feeding is a reduction in intake of the basal diet (pasture), such that the total intake does not increase proportionately with intake of grain. This phenomenon is known as the substitution effect and it is a critical factor which affects the efficiency of utilisation of grain supplements in particular. The substitution effect is usually defined quantitatively as the unit decrease in pasture intake per unit supplement intake. The substitution rate can vary from zero to greater than 1 .0, depending on a variety of factors, most important of which appears to be the quality of the basal diet and the level of supplementation. Substitution is more likely with high than with low quality forage (Favedin *et al.* 1991; Rowe et al. 1991).

These principles have been clearly illustrated and explained recently by Schiere and de Wit (1995) using the model of Tolkamp and Ketelaars (1992) who proposed a formula equating total organic matter (OM) intake to various parameters relating to the quality of the basal diet and the intake of the concentrate. The effects are illustrated in Figure 5 for straws of different quality. This theoretical relationship suggests that, with higher quality feeds, intake of the basal diet is reduced even when low levels of supplementation are fed. This is supported by data presented for grain-based rations in the review of Rowe *et al.* (199 1). By contrast, with lower quality feeds and low levels of supplementation with nutrients which are limiting, intake of the basal diet is increased (see Figure 5). This reinforces the need, when feeding concentrates, to ensure the supply and balance of microbial substrates is appropriate. In practice, this is usually achieved by fortifying the grain source with a source of non-protein nitrogen and sufficient sulphur for its maximum utilisation.

The substitution effects associated with feeding protein meals are not well defined. This situation is largely a reflection of the generally low levels of feeding used and it is only in recent experiments that the higher intakes of protein meals have been exam-

Figure 5 Schematic representation of effects of concentrates on the intake of roughage and total organic matter (OMI) for a low quality (solid lines) and higher quality (dashed lines) straw. Adapted from Schiere and de Wit (1995) and based on equations of Tolkamp and Ketelaars (1992).

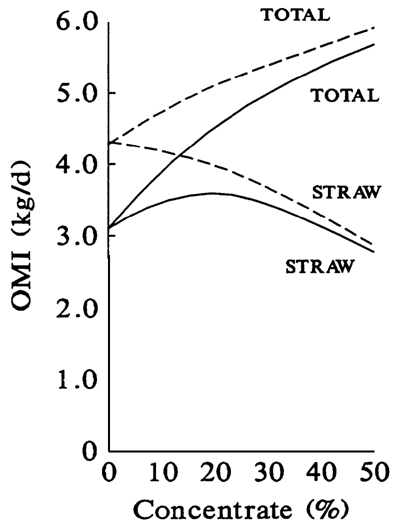
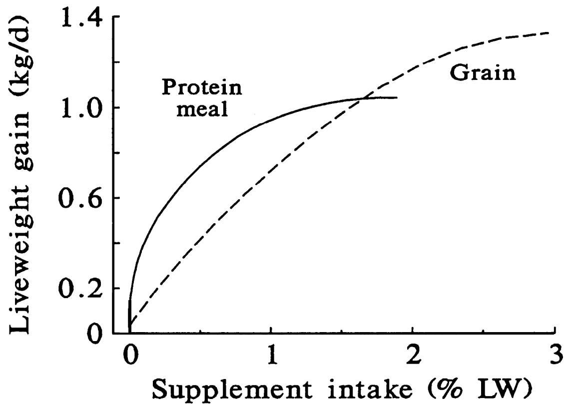


Figure 6 Theoretical model of liveweight response to protein meal or grain supplementation.



ined. In our own experiment in which weaner steers (145 kg Iiveweight) were given Rhodes grass hay and fed cottonseed meal at intakes ranging from 0 to 1500 g/d, intake of hay was increased by 28% with the first increment of cottonseed meal and there was no depression in hay intake with even the highest level of cottonseed meal (McLennan and Poppi, unpubl. data). However, in the recent experiment reported by Dolberg and Finlayson (1995), when ammoniated straw was fed to steers with intakes of cottonseed cake of 0, 0.4, 0.8, 1.2 and 1.6% of liveweight/d (0 to 4 kg/d), corresponding intakes of straw were 2.6, 2.5, 2.1, 1.9 and 1.3% of liveweight/d, illustrating an increasing substitution of protein meal for straw. The difference in the two sets of results may have arisen because soluble nitrogen was limiting with the Rhodes grass and was supplied by the cottonseed meal, but was not limiting with ammoniated straw.

Proposed model of liveweight response

A stylised model is offered in Figure 6 to represent probable response relationships when either protein meals or grain are fed in increasing amounts to young growing cattle on low quality pastures. This model is based on the data collated from the literature and presented earlier, and also on the theoretical supply of nutrients from the supplements with recognition of their probable effects on intake of the basal diet. This exercise is necessitated by a lack of appropriate data from experiments in which the different types of supplement have been compared.

In the model, the response to protein meal is greater at low intakes than with grain in keeping with the higher P/E ratio of nutrients supplied to the animal (Leng 1990), the probable greater supply of nutrients limiting rumen microbial growth and an expected stimulation, rather than depression, of forage intake. Animals respond to the higher P/E over most of the response surface until liveweight gain plateaus out at around 1 kg/d. The reason for this effect is unclear but may reflect an increasing substitution effect (see Dolberg and Finlayson 1995), a limiting supply of energy substrates to utilise the available nitrogen, excess ammonia concentration in the rumen, or a combination of all of these. It is possible that at higher intakes of protein meal, inclusion of grain source would be beneficial. This aspect deserves further attention.

With the grain-based ration, it is assumed that there is an adequate supply of rumen degradable nitrogen and other nutrients for optimal microbial growth. Nevertheless, the response curve is less steep than with the protein meal due to the lower P/E ratio and expected higher substitution effects. The animals, however, continue to grow at higher intakes beyong the 1 kg/d limit apparent with protein meals as the intake of metabolizable energy increases, partly through substitution of grain for forage, in the presence of an appropriate P/E ratio in the available nutrients. If intake of grain is not limited the growth rates should approach those achieved under feedlot conditions. The challenge is now to test this model in order to allow appropriate profitability assessments to be made.

Conclusions

Knowledge of the effects of different supplement types on animal performance is increasing but the translation of this knowledge into predictions or into practical strategies for use by cattle producers requires an increased understanding of the way in which these supplements impact on the nutrition of the grazing animal. New feeding systems allow better estimates of the supply of nutrients to the animal for absorption and assist in the understanding of the responses achieved. However, there still remains a need for well designed, dose response type feeding trials in which the animal's growth is the ultimate measure of response to different inputs.

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