FURTHER OBSERVATION ON THE EFFICIENCY OF FEED UTILISATION FOR GROWTH IN RUMINANTS FED FORAGE BASED DIETS,

R.A. Leng

SUMMARY

Optimising herbivore nutrition is discussed in the light of the fermentative digestive system and the balance of nutrients that arrive at tissues of ruminants for metabolism.

The forages from unimproved pastures available to ruminants are often of low quality i.e. digestibility below 55% and seldom 'deliver' for absorption the balance of nutrients required by the animal.

Primary microbial nutrient deficiencies in the rumen often lower the ratio of the microbial cell protein available to the animal relative to the volatile fatty acids absorbed. Under a number of grazing conditions forages are low in protein and except for the early growth stages ruminants tend to consume low quantities of dietary protein with little or no protein that escapes the fermentative processes of the rumen.

P/E ratios in the nutrients available for digestion and absorption in ruminants consuming forage based diets can be low through combinations of inefficient rumen microbial growth or a low rumen-bypass of protein.. In all cases a low P/E ratio results in inefficient utilisation of absorbed nutrients by the animal and may result in a high heat increment of feeding. The production of metabolic heat, at times may lower feed intake where animals are already experiencing a heat stress because of climatic conditions, heavy coat insulation or because of a high basal metabolic rate.

Recent reports of a heat stress syndrome in feed-lot cattle is tentatively related to a potentially high heat increment of feeding coupled with a high environmental temperature/humidity.

INTRODUCTION

Australian ruminant industries are mainly based on pastures with little use of supplements except in drought.

Low quality forages (i.e. low in protein and digestibility) support only low levels of production. In the past, production per animal has been sacrificed for production per hectare because of the relationship of stocking rate and productive function shown. in Fig. 1.

Professor of Nutritional Biochemistry, Department of Biochemistry, Microbiology and Nutrition, University of New England, Armidale N.S.W. 2351 AUSTRALIA

The production of ruminants on native pasture over a 12 month period seldom rises above about 30% of the genetic potential and has been summarised by Walker (1987) see (Fig. 2).

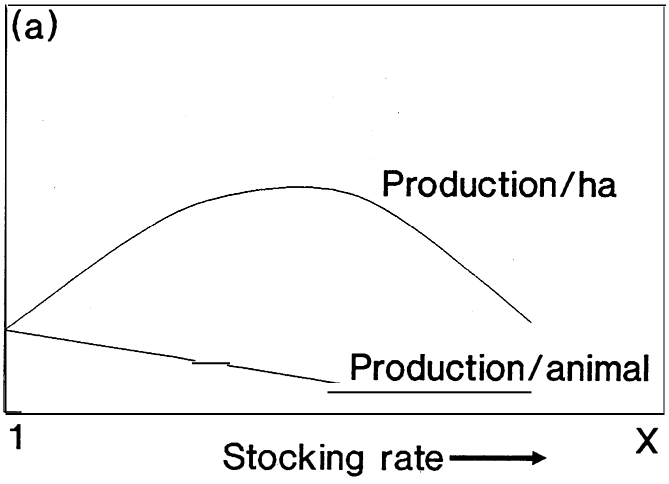

Fig. 1 Liveweight gain in relation to stocking rate (after Jones and Sandland 1974).

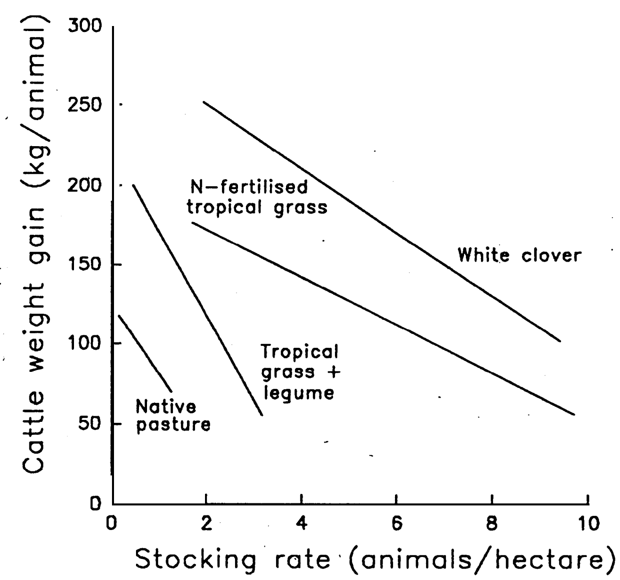

Fig. 2 The relationship between stocking rate and production per animal for cattle grazing native pastures, improved native pastures and temperate pastures (after Walker 1987):

In the last 20 years there has been a growing recognition that forages and in particular low protein forages are inefficiently used for liveweight gain because of an imbalance in the protein to energy ratio in the nutrients available for absorption (termed the P/E ratio) (See for review Preston & Leng 1987).

This author believes that the key to improvement of livestock production in Australia and the answers to many ill thrift syndromes lies in finding ways to optimise the P/E ratios of the nutrients absorbed. When P/E ratios are increased, surprisingly high efficiency of feed utilisation are achieved by sheep and cattle on low quality forages with concomitant increases in productivity. These feed conversion efficiencies are often 10 to 20 times those predicted from conventional feeding standards. This throws doubt on the basis of most feeding standards particularly those emphasising the metabolisable energy content of a diet.

Supplementation to achieve high P/E ratios in animals using supplements have been discussed in previous Recent Advances symposia (1987, 1989). In the present paper I wish to attempt to rationalise some of the conundrums that inevitably arise when attempting to manipulate the interactive systems of the rumen microbial ecosystem or the animal's metabolism or both.

The recent crisis associated with cattle deaths in feedlots are discussed in relation to a possible interaction between nutrition/metabolic heat production and climate.

CHEMICAL COMPOSITION OF LOW QUALITY FORAGES

The nutritional value of forages, is often categorised from the crude chemical composition of the forage and its metabolisable energy (ME) content. The latter is often obtained from ***in vitro*** digestibility measurements. Although measurement of digestibility and analyses that indicate cell solubles and cell wall materials are highly useful for studying the fermentative characteristics of a forage, they often bear little'relationship to its feeding value (Preston & Leng 1987). Feeding value is determined more by the efficiency of feed utilisation than the ME of a feed or even ME intake.

Efficiency of feed utilisation in ruminants is dependent on:-

(1) the balance of nutrients available to the rumen microbes that digest the feed and

(2) the quantity and balance of nutrients available to the animal from the digested feed in relation to its requirements.

FACTORS EFFECTING MICROBIAL GROWTH IN THE RUMEN

On forage based diets, low in true protein, ruminants depend almost entirely on fermentation end-products for their nutrient supply. In general the nutrients can be grouped into glucogenic and acetogenic volatile fatty acids (VFA) and the components of microbial cells i.e. amino acids and long chain fatty acids arising in digestion within the intestines. Dietary long chain fatty acids and protein are also available from the lower digestive tract in variable quantities depending on the forage and supplement. The ratio of microbial cells to VFA produced and the extent to which dietary protein escapes to the lower tract are the major determinants of the protein to energy ratio in the nutrients.

absorbed by ruminants fed poor quality forage. This ratio is called here simply the P/E ratio.

By definition microbial growth efficiency is the ratio of microbial cells synthesised per unit of ATP available to microbes from the conversion of plant components to VFA,

The factors that influence the efficeincy of net microbial growth and therefore the P/E ratio in the nutrients absorbed from forages are:

* an optimum availability of critical nutrients for microbial growth (determines efficiency of use of ATP for synthesis of the components of microbial cells)

* the lysis of microbial cells within the rumen and fermentation of the components (determines the quantity of cells produced in the rumen that leave for digestion in the intestines).

Availability of critical nutrients for microbial growth in the rumen

Under the anaerobic conditions that pertain to the rumen, the optimum efficiency of microbial growth expressed as g dry cells produced per mole ATP available (i.e. Y-ATP) is theoretically about 30g/mole ATP. The efficiency of microbial growth is however related to the availability of the least limiting nutrient for the specific microbes present. In any diet this might be a mineral, a trace element, ammonia or some precursors of microbial cells. The actual requirements will depend on the microbial ecosystem which in turn depends mainly on the major carbohydrate component of the forage (see Maeng et al. 1989). There will be a critical level of a nutrient at which microbial growth efficiency will be decreased to the extent where microbial pool size is diminished. Above this critical level progressive correction of the deficiency will increase microbial growth efficiency and therefore P/E ratio in the nutrients absorbed to an optimum level.

The digestibility of a forage will probably be optimised at a microbial growth efficiency which is lower than that which optimises the P/E ratio. For example stepwise increase of ammonia in the rumen of steers fed rice straw and infused intra-ruminally with urea indicated that digestibility was optimised at 80-100mg ammonia N/l of rumen fluid but feed intake increased until the ammonia level reached 200mg N/l. The increased straw intake as a result of treatment, contrary to previous suggestions (see Perdok *et al.* 1988) is now believed to be a result of an improved P/E ratio through greater microbial growth efficiency (see Leng 1990).

The implications of these observations (see also Krebs & Leng 1984; Boniface et *al.* 1986) are that for optimum utilisation of a forage, ammonia levels in the rumen should not fall below 200mg N/l. However, where a bypass protein is supplemented it may only be necessary to achieve 100mg N/l for optimum digestibility since it will be as effective to adjust the P/E ratio by feeding a protein supplement which bypasses microbial degradation in the rumen.

Protein supplements also invariably contribute to the ammonia -N pool in the rumen through degradation of the soluble components in the rumen and from recycling of N to the rumen since a proportion of the absorbed amino acids are deaminated in the animal. Urea is recycled to the rumen in saliva and across the rumen wall (see Leng and Nolan (1984) for review).

The point is again stressed that for optimum utilisation of a low quality forage fed alone to ruminants, rumen ammonia levels in excess of 200mg N/l are necessary. However, where the feeding strategy includes the use of bypass protein supplements the critical rumen ammonia level is that which optimises digestibility i.e. about 100mg N/l. The need for NPN when protein supplements are given is lowered as the level of protein supplementation is increased and will often not be necessary at high rates of protein supplementation.

The major factor involved in lysis of bacteria in the rumen is probably the activity of rumen protozoa which predate bacteria (the effects of protozoa are discussed later).

P/E RATIO AND FEED CONVERSION EFFICIENCY

In the last two decades there has been a gradual recognition that the efficiency of utilisation of forage by ruminants for growth improves progressively and substantially as the P/E ratio in the nutrients absorbed increases (see Fig. 3).

In the past the effects of increasing the P/E ratio in the nutrients absorbed has been confused by two effects which may impact singly or together depending on environment. Most of the early work on supplementation with urea and bypass protein to improve the P/E ratio indicated large effects on voluntary feed intake. This appeared to explain the increased production responses (see Leng *et al.* 1977). However, as more research was reported some results indicated that protein supplementation *per se* increased efficiency of forage utilisation and at times did not effect forage intake (see 'Kellaway and Liebholz 1981). This was extremely confusing since the effects of protein supplementation appeared to be contrary to the theories of appetite control in ruminants in which distention of the rumen played the most important role in low quality forage based diets. Just as others have surmised (Ketelaars & Tolkamp, 1991) the effects of bypass protein supplementation on forage intake appeared to be related more to the efficiency of feed utilisation than the bulk distention of the rumen (see Leng 1989b).

Rationalisation of the different feed intake responses becomes critical to our understanding of nutrient requirements of ruminants. An explanation for the differences was first put forward by Leng (1989a) and developed further as more information has come forward (see Leng 1989b and Leng **1990.)**

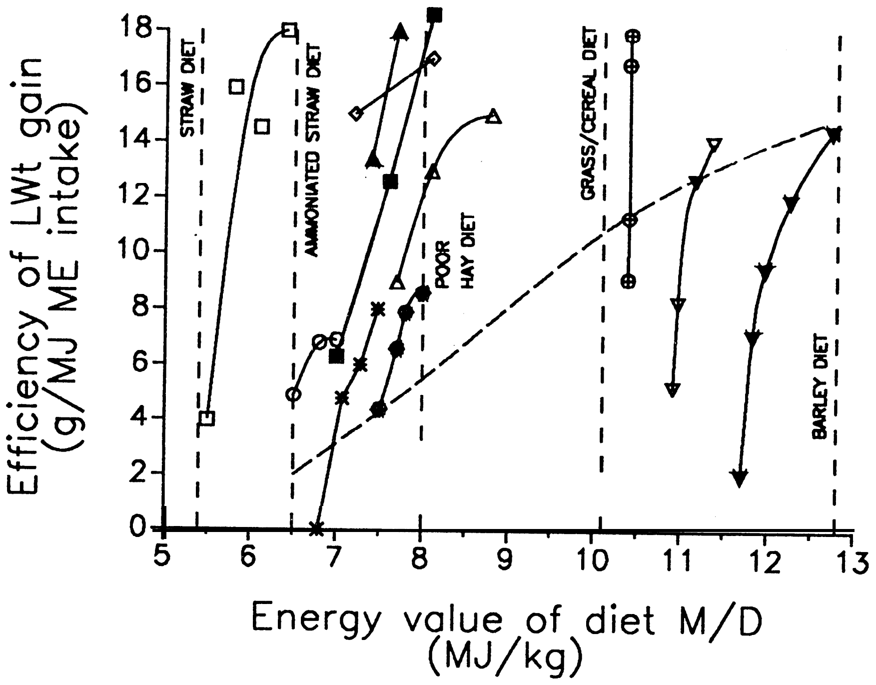

Fig. 3 A schematic relationship between metabolisable energy content of a forage (in MJ/kg DM; M/D) and feed conversion efficiency (g liveweight (LWt) gain/MJ ME) (from Webster 1989). The relationships found in practice with cattle fed on straw or ammoniated straw with incremental amounts of bypass protein supplements in Australia (◇, ○, ●) (Perdok *et al.* 1988), Thailand (△) (Wanapat *et al.,* 1986) and Bangladesh (□) (Saadullah 1984). The results of Godoy & Chicco (1990) ( ) were obtained withcattle on tropical pasture hay harvested in the dry season and supplemented with cottonseed meal in Venezuela. Hennessy et *al. (1989)* (■) used cattle fed on a poor-quality tropical hay supplemented with copra meal.

For comparisons similar responses to bypass protein supplement for cattle fed molasses (▽) and sugar cane (▼) based diets are shown (Preston *et al.* 1976, Preston & Willis 1974). In these trials feed intake did not increase with supplementation. The results for silage based diets supplemented with fish meal are from Iceland (⊕) Olaffson and Gudmundsson (1990) where feed intake was increased by supplements of fishmeal.

In outline the explanation that developed hinged on early observations by Blaxter and his colleagues (see Graham et *al.* 1959) which apparently showed that acetic acid the major energy-nutrient absorbed by ruminants could be readily 'burned off' when added to all forage based diets and considerable metabolic heat was produced.

Ruminants appear to be highly sensitive to heat stress (see Blaxter 1962). Evaporation of perspiration from the body surface is the major physiological method of cooling, but the ruminant has only 0.2 of the capacity of humans to dissipate heat by this route per meter of body surface. They are therefore highly sensitive to an extra heat load if they are in a hot/humid climate. Similar heat sensitivity might occur if they have a highly insulative coat in a moderately warm climate, and/or have a high metabolic rate following introduction from a cold environment into a warm animal house. In support of the latter Farrell & Corbett (1970) demonstrated that sheep following shearing have a persistent and substantial increase in basal heat production for up to 135 days post shearing long after the cold stress has been ameliorated through increased fleece insulation.

To rationalise the different observations of supplementation on feed intake Leng (1989a) suggested that supplementation of cattle with a bypass protein stimulates intake of low quality forage when animals are heat stressed and have already reduced intake in the unsupplemented state to accommodate this stress. The theory is that a metabolic heat load superimposed on a hot environment reduces feed intake. The metabolic heat load is removed by balancing nutrients to the animals needs by supplementation. The research in Australia from which this concept arose is shown in Fig. 4.

P/E RATIO AND THE EFFICIENCY OF ACETATE UTILISATION.

The controversy that has surrounded research from various laboratories on the efficiency of utilisation of VFA for growth in ruminants has absorbed the interest of animal scientists since the early reports of a high heat increment in sheep when exogenous acetate was added to a diet of dried and cubed grass (see Graham et al. 1959; Blaxter 1962). The heat increment was assumed to be a "burning off" of the acetate load which could not be used in anabolism because of the imbalanced nature of the nutrients available to the animal (see Blaxter 1962).

Research over the last 30 years, however, appeared to discount this thesis. The subsequent research did not however repeat the work of Blaxter and his colleagues who fed sheep cubed, dried rye grass. The feed description suggests that the forage was dried at low temperatures; the fibre was in a long form and not ground and not subjected to a prolonged heat in cubing. Under these circumstances, the protein in the dried grass could be expected to be soluble, and readily fermented and the forage would also remain in'the rumen for a substantial period allowing complete degradation (see MacRae 1976). This forage could also have supported a considerable protozoa1 population density within the rumen, which would ensure a low microbial protein flow out from the rumen (see for discussion on this point Bird et al. 1990). The net result of both a high dietary protein degradability and high protozoa1 population in the rumen would have been a low P/E ratio in the nutrients absorbed. Acetate infusion into these sheep could have created a severe imbalance in the ratio of

VFA to amino acids at the tissue level and may have necessitated rapid removal of the excess acetate in heat producing metabolic cycles.

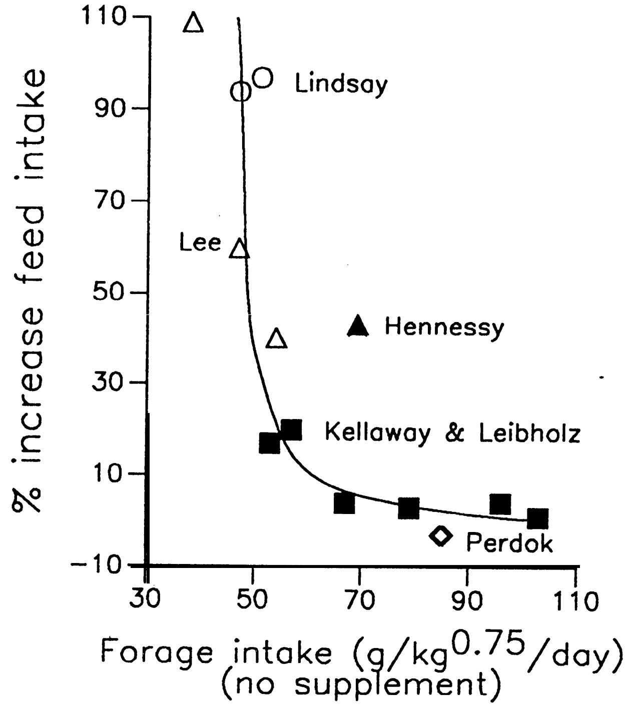

Fig. 4 Intake of low-quality forage by cattle (studies are only considered from Australia) in relation to intake of the forage following supplementation with a bypass protein meal or bypass protein meal plus urea in different climatic zones (Leng 1989a). The research of Lindsay & Loxton (1981), (○) Lindsay *et al.* (1982) (○), Lee *et al.* (1987) (△) and Hennessy (1984) (▲) was done at sites in the tropics or subtropics, whereas the research of Kellaway & Liebholz (1981) (■) and Perdok & Leng (1990) (◇) were done under more temperate climate conditions.

A review of other reported studies, concerned with testing the high heat increment of feeding acetate have used basal diets of hay or hay plus concentrates and often fed protein meals which for reasons of physical form (i.e. ground high protein hay) or the high content of potential bypass protein would provide a high P/E ratio in the nutrients absorbed by the animals. Increasing the availability of acetate to ruminants on diets with a high P/E ratio may be beneficial as the acetate availability from the rumen would be relatively low and the excess acetate would be used in oxidative metabolism to provide ATP for tissue synthesis. Therefore the metabolic heat load would not be so high. The high P/E could also allow acetate to be utilised efficiently in synthesis of long chain fatty acids.

In recent studies with sheep fed straw based diets (adequately supplemented with urea and minerals), the addition of a bypass protein meal, propionate or both, showed that these supplements stimulated protein and fat synthesis respectively (van Houtert and Leng, unpublished observations 1991) (see Table 1).

Table 1 Estimated composition of fleece-free live-weight gain of lambs offered a basal diet of ammoniated barley straw, supplemented with HCHO-casein (HC) and Na-propionate (Prop) over a period of 155 days (van Houtert, M. and Leng, R.A. unpublished observations 1991).

Groups*	Composition of body-weight gain+			
	Water (g/d)	Fat (g/d)	Protein (g/d)	Energy (kJ/d)
Control	12.6	0.8	3.6	116
+Prop	8.3	6.2	2.3	298
+HC	26.5	7.6	8.1	491

* HC and Prop refer to the supplements of formaldehyde-treated casein (50g/d) and Na-propionate (20 g/d) respectively.

The inference that can be drawn is that acetogenic substrate is used inefficiently on diets that provide a low P/E ratio in the nutrients absorbed and a considerable proportion is directed to heat production without accomplishing work or coupling ATP to synthesis of tissue components or fat.

This is supported by feeding trials in which the efficiency of feed utilisation for growth is increased greatly by increasing the P/E ratios by supplementation with a bypass protein (see Fig. 3) or by manipulation of the microbial mix within the rumen (i.e. defaunation) see Bird et al. 1990 also Table 4).

The relationships between efficiency of feed utilisation and metabolisable energy content of a diet is shown in Fig. 3 for a variety of diets where a supplement had no effect on intake or intake was deliberately kept constant (with the exception of the silage based diet). It is interesting that the trends shown also apply to a wide variety of basal feeds, not only low quality forages. It is the diets that support the highest protozoal densities in the rumen of cattle that are used with the least efficiency (i.e. sugar cane and molasses).

CLIMATE/NUTRITION INTERACTIONS

The data in Fig. 3 indicate that on high digestibility forages (silage, sugar cane) or energy dense diets (molasses) or low quality forage based diets (straw, treated straw or dry native pasture hay) the efficiency of feed utilisation for liveweight gain of cattle can be improved from between 4 and 18 times by correcting an imbalance in the P/E ratio in nutrients absorbed.

In a number of experiments, forage intake by cattle has been reported to increase substantially in response to altering the P/E ratio by supplementation, this increase has been from 0 to over 100% with the highest responses often coming from research trials conducted in the tropics (see Fig. 4).

Improved feed intake through supplementation of cattle on forage based diets with bypass protein has not however, been restricted to research under tropical conditions. With cattle on silage based diets in the U.K. and Iceland, supplementation with fish meal has at times elicited large responses in feed intake. The research from Iceland is extremely interesting as it showed a substantial increase in grass silage intake by cattle to supplements of fish meal but a depressing effect of fish silage on intake (see Fig. 5). The latter effect could be interpreted as a further imbalancing of the- P/E ratio by the soluble protein source which when fermented totally would provide less microbial protein to VFA than an equivalent amount of carbohydrate.

In studies from the U.K. the effects of increasing increments of grain on a silage based diet (which have minimum effects on P/E ratio) and fish meal (which improves P/E ratio) on liveweight gain relative to metabolisable energy intake of cattle had considerably different effects (Fig. 5). The heat increment of feeding appears to be increased by feeding grain with approximately 50% of the metabolisable energy of the grain being unaccounted for (decreased feed conversion efficiency) when no extra protein was made available. The other observation is that the efficiency of utilisation of metabolisable energy by cattle is quite different at the various research locations.

The decreased efficiency response to supplementation with grain may also be explained by an increased fat deposition in the tissues of cattle on the silage diets with increasing grain content. Similarly the research of Silva *et al.* (1989) when examined in the same light showed a decrease in the conversion of ME to liveweight gain in cattle when a supplement apparently increased the overall digestibility of the diet but had no effect on P/E ratio (the supplement in this case was sugar beat pulp). However, when P/E ratios were increased by adding a fish meal supplement the efficiency of use of ME was improved (see Table 2). Recent studies by Hennessy and Williamson (1990) indicate that supplementation of cattle on poor quality forage diets with maize grain was extremely wasteful when compared to fish meal supplements (Table 3).

Another striking difference in results from feeding trials is also highlighted in Fig. 5. The extrapolated intercepts of metabolisable energy requirements for maintenance of cattle are vastly different between research institutes in different localities, as are the slopes of the responses curves to adjusting P/E ratio with supplements. These data indicate that where feed intake remained constant when supplements were given, the improved production was a response to increased efficiency; whereas where intake improved with supplementation the increased production was a composite of improved nutrient availability and improved efficiency of feed utilisation. It can however, be seen that the dominant effect of supplementation with bypass protein is on the efficiency of nutrient utilisation.

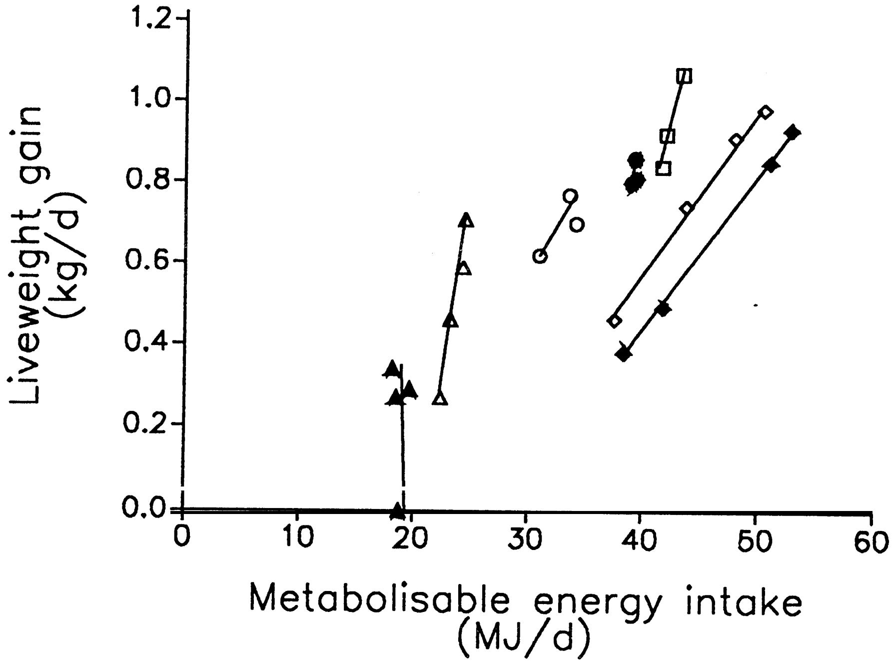

Fig. 5 The effects in cattle of feeding increasing levels of bypass protein meals on liveweight gain in relation to metabolisable energy intakes on (1) straw based diets (▲), and ammonia treated straw (△) supplemented with 0.6kg rice bran/hd/d plus molasses urea blocks and various levels of cottonseed meal (Perdok & Leng 1990); (2) grass silage (GS) plus 372g barley/d (○) and three levels of fish meal (0, 41, 82g/d); (3) GS plus 921 g barley and three levels of fish meal (●); (4) GS plus 1478g barley/d and three levels of fish meal (□) (Owen & Ochoa 1982); (5) a silage based diet with 4 levels of fish meal (◇) and (6) a silage based diet with 3 levels of fish meal (◆) and one level of fish silage (◆) (Olafsson and Gudmundsson 1990). The cattle in the three studies weighed initially 275kg, 108kg and 180kg respectively.

In the research conducted in Iceland the animals had a high heat generation which was different between animals on experiments at different times (also compare these with the results of Owen & Ochoa (1982); Ochoa-Ortega (1983); Perdok and Leng (1990) whereas in the studies of Perdok and Leng (1990), the intercepts for the response curves of growth of cattle given various levels of bypass protein and treated or untreated straw diets were closely similar. The conclusions that can be drawn here are that in the Icelandic work the animals had a high metabolic heat production which may have resulted in a heat stress in the unsupplemented state and that as the balance of nutrients was adjusted to requirements the efficiency of feed utilisation improved sufficiently to remove the heat stress and allow substantial increases in intake. In contrast supplementation with fish silage further imbalances the P/E ratio (as microbial growth efficiency on protein substrate is about half that on carbohydrates) and resulted in an increased heat increment, further heat stress and a further reduction in silage intake. The animals in this case were brought inside from grazing and may have had a high metabolic rate and a highly insulative coat induced by cold conditions.

Table 2: The relationship between metabolisable energy content of a forage (ME: dry matter (DM) (M/D; MJ/kg) and efficiency of growth (g gain/MJ ME intake) in cattle fed on wheat straw (US) or ammoniated straw (AS) with supplements of fishmeal (FM; 50g/kg straw) or sugar beet pulp (SBP; 150g/kg straw) (adapted from Silva et *al.* 1989 by Leng 1990).

		LWt gain (g/d)	M/D	Efficiency (g LWt gain/ MJ ME)
Treatment				
Cattle	US	-24	6.0	
	US + FM	176	6.4	5.3
	US + SBP	183	7.1	4.5
	US + SBP + FM	337	7.7	6.6
	AS	198	7.0	4.6
	AS + FM	423	7.4	8.6
	AS + SBP	262	8.0	4.7
	AS + SBP + FM	814	8.3	12.6

Table 3: Organic matter intake (OMI), liveweight gain (LWt) and efficiency of liveweight gain of cattle (180-215kg) fed a poor quality sub tropical native pasture hay (NP) with a complete mineral supplement and supplemented with: Group 1 - O(NP); Group 2 - 75g urea (U); Group 3 - 75g U + 400g maize flour (M); Group 4 - 280g formaldehyde casein (FC) (adapted from Hennessy and Williamson 1990).

Group	Diet	OMI (kg/d)	LWt gain (g/d)	Efficiency (g LWt gain /MJ ME)
1	NP	4.02	100	4.0
2	NP + U (75g)	4.37	290	10.7
3	NP + U (75g) + M (400g)	3.99	340	11.7
4	NP + FC (280g)	4.29	600	20.0

The conclusions is that there appears to be a marked interaction between climate and nutrient requirements and

. between climate and the ability of an animal to consume large quantities of forage. Even on unsupplemented diets which elicit a high heat increment of feeding, unless the animal has a highly insulative coat and/or is at an environmental temperature and humidity which does not allow it to dissipate heat, the consequences of the extra heat load are not severe. However, where these environmental conditions prevail animals with imbalanced P/E ratio in their nutrients will need to reduce feed intake to reduce metabolic heat load. Similarly if animals have induced high metabolic rates from living in a cold environment then when brought inside they could suffer a major heat stress on an imbalanced diet.

P/E RATIO AND RUMEN PROTOZOA

The differences between faunated and fauna-free lambs in productivity from a wheat-straw based diet supplemented to ensure no deficiencies of nutrients for the rumen microbes and with additional starch or protein supplements is shown in Table 4.

Clearly fauna-free animals use their feed more efficiently for liveweight gain and wool growth. Because wool growth is an index of protein entering the duodenum (see Reis & Schnickel 1961, Ferguson 1975, Leng et al. 1984), the increased efficiency is consistent with a higher P/E ratio in the nutrients absorbed in the unfaunated animals compared to control animals,

Practical methods are presently being developed to manipulate rumen protozoa, which should become another method to be added to a battery of methods to be used to improve P/E ratio and therefore optimise forage utilisation by ruminants.

P/E RATIO AND REPRODUCTIVE EFFICIENCY

One of the major limitations to productivity of ruminants on native pastures is the low reproduction rates. The effects of supplements to increase P/E ratios in the nutrients absorbed have resulted in higher growth rates of young animals shortening the time to puberty by one to two years (Hennessy 1984) and it is possible to have cattle fed largely crop residues but supplemented with protein meals calving at 2-3 years of age whereas 4-5 years of age is more normal.

Evidence is now building which demonstrates that in sheep fed poor quality forages improving the P/E ratio with supplements leads to increased ovulation rates (Nottle et al. 1987) and in large ruminants more of the herd becoming pregnant in a shorter mating season. Sheep and cattle on poor quality forages often produce smaller lambs and calves (Stephenson and Bird 1987, Lindsay and Loxton 1981). Small lambs are often observed in sheep under hot environmental conditions and from the discussions above it appears that they are possibly small through an interaction of nutrition and climate rather then heat stress per se. Supplementation in the last trimester with bypass protein resulted in more normal birth weights and greater viability of lambs leading to

Table 4 Calculated metabolisable energy (ME) content of diets M/D (MJ/kg DM); intake of ME and efficiency of use of ME for liveweight gain in **faunated** (+P) and fauna-free (-P) lambs. The basal diet was wheat straw/minerals and urea. The treatments were Group 1; basal diet; Group 2; basal diet supplemented with cottonseed meal (CSM), Group 3; basal diet **supplemented** with maize (M), Group 4; basal diet supplemented with maize plus cottonseed meal.

Group		Intake of Straw (gDM/d)	Intake of Supplements Maize (gDM/d)	CSM (gDM/d)	Total DMI(D) (g/d)	MJ from diet components Straw	CSM	Maize	Total (M)	M/D (MJ/kg DM)	LWt gain (g/d)	Efficiency of LWt gain (g/MJ)
1	+P	492	0	0	492	2.71	-		2.71	5.5	-18	-
	-P	557	0	0	557	3.06			3.06	5.5	-2	-
2	+P	532	0	74	606	2.93	.89		3.82	6.3	+9	2.4
	-P	576	0	74	650	3.17	.89		4.06	.2	+26	6.4
3	+P	499	147	0	644	2.75	-	2.16	4.91	7.6	+22	4.5
	-P	540	147	0	684	2.64		2.16	4.80	7.0	+45	9.4
4	+P	456	147	74	674	2.51	.89	2.16	5.56	8.2	+43	7.7
	-P	516	147	74	734	2.84	.89	2.16	5.89	8.0	+58	9.9

Assumption

ME Straw = 5.5 MJ/kg
ME Maize = 15 MJ/kg
ME CSM = 12 MJ/kg

significant improvements in survival of the young animal (Lynch *et al.* 1990).

The extent of the improvement in reproduction rate to manipulation of the P/E ratio in ruminants requires considerable research particularly to define feeding strategies, strategic supplementation and economic responses. A 25% increase in reproductive rate can be much more economic than all other benefits that accrue from feeding a protein that escapes fermentative digestion.

IMPLICATIONS OF BALANCED NUTRITION FOR FEEDLOTS

Feedlot nutrition is based on a high proportion of grain in the diet. There are two reasons for using high levels of concentrates feeding. The first is logistic; such production systems require the transportation of very large quantities of feeds and to reduce costs these must therefore be dense and have a high digestibility. The second reason for the use of grain is the concept that high growth rates and efficiency of feed conversion required. in practice can only be achieved on concentrate based diets.

There is a third reason for feedlotting which involves certain tastes and odours in the meat from pasture fed ruminants that are lost if the animal is fed grain based concentrates for 100 days.

The feedlot industry which probably began with the development of the Barley-Beef systems in Scotland in the 1950's has traditionally been used to reliably supply markets with meat that is of a standard quality.

There are a number of factors that have assisted the feed-hot industry to have less rigorous nutritional standards.

These include:-

* for logistic reasons most feedlots are in cool areas or areas that are hot but dry.

* maize and sorghum grain fed at a high proportion of the diet allows some starch to escape fermentation to a variable but significant extent ensuring an adequate supply of glucose to the animal at all times.

* the protein of grain tends to be quite well protected and bypasses the rumen (Klopfenstein *et al.* 1991) reducing the requirements 'for bypass protein from other sources.

The glucose and protein that is made available from grain ensures that the nutrients available from such diets are seldom out of balance to the same extent as on forage based diets. On the other hand starches of barley and wheat are often well digested in the rumen and for dietary purposes there are requirements for inputs of soluble N and bypass protein.

Concentrate based diets are at times deficient in fermentable N unless non-protein nitrogen and soluble fermentable protein are supplied in stoichiometric amounts.

A recent review comparing concentrate and forage based diets in terms of the efficiency of use of metabolisable energy concluded that the high heat increment associated with forage based diets may be due to the extra energy needed to chew, swallow and move digesta along the tract as compared with similar processes in cattle on concentrate based diets (Ørskov & Macleod 1990). The explanation for low heat increment on grain based diets is not supported by evidence from one of the authors own publications which shows contrary results (see Table 2). Fig. 3 also shows that feed conversion efficiency on straw based diets supplemented with protein meals can be much higher then predicted for grain based concentrates (see Webster 1989).

Undoubtedly cattle on grain based diets can be imbalanced and have a relatively high metabolic heat production at times. The situation where this'would arise is where a basal diet of grain (7-12% CP) contains little non-protein-nitrogen and bypass protein.

The postulated reasons for a high heat increment in cattle on grain that is low in protein are the same as discussed earlier. A low rumen ammonia (or some other microbial nutrient e.g. S, P.) leads to an inefficient microbial growth in the rumen and a low P/E ratio in the end product produced (i.e. microbial cells and VFA) which increases the requirements for bypass protein. If the N deficiency in the. rumen is extreme and bypass protein low or absent the P/E ratio may not meet the requirements and the metabolic heat increment can be high.

Heat stress and feedlot nutrition

In a hot/humid period the high heat increment of feeding may be sufficient to create a heat stress which normally causes animals to reduce feed intake. A heat stress, however, would only lead to death of the animal under a particular set of circumstances. It could arise for instance, if prior to a high ambient temperature/ humidity the animals had been cooled by rain, (which may reduce feed intake temporarily) and then fed in the coolness of the morning. The period of low feed intake followed by a cool period early in the morning, would allow a large voluntary consumption of grain which could be ingested quickly. This would be fermented in the rumen reaching a maximum rate at 4-6h after feeding (12-2 pm). If there was an imbalance on the nutrients then metabolic heat production would also peak at 4-6 h after feeding. If this coincided with a hot/humid period in which animals would normally only just be able to maintain body temperature then a heat produced by a depression of feed conversion from say 6:1 to 7:1 could raise the body temperature from 10-15°C. Death would result at a 6-7°C rise in body temperature.

Diets that are now commonly used in feedlots have all the prerequisite characteristics. i.e. 50-80% barley, 10% cotton seed hulls or 20% corn silage,, 3-5% molasses with 4% minerals, 2% tallow and often less than 5% cotton seed meal.

Chicken manure/heat stress

Chicken manure is a source of many critical nutrients which will ensure an efficient rumen fermentation, these nutrients include minerals, non-protein nitrogen and even amino acids all or any of which, might be deficient in a feed-lot diet and could lead to a low P/E ratio in the nutrients absorbed from the gut of cattle.

Undoubtedly the inclusion of chicken manure in a diet of grain could reduce the postulated high heat increment and therefore possibly heat stress. The ban on the use of chicken manure in feedlot rations needs to be re-examined-and possibly be rescinded provided certain safeguards are put in place to ensure the absence of toxins.

Death from heat stress in ruminants would require an extremely high temperature/humidity for a prolonged period or a set of circumstances leading to thermal embarrassment as indicated above. In the authors research in India with dairy cows , levels of production of 25-35 1 of milk per day have been maintained in diary cows at environmental temperatures exceeding 45°C when fed diets high in bypass protein. Whilst these animals showed signs of heat stress they continued to produce at a rate which is at least equivalent in nutrient demand to that of cattle being fattened in a feedlot.

CONCLUSIONS

Over the past 30 years a body of research has emphasised that it is the efficiency of feed utilisation which largely determines the level of production of a ruminant on forage based-diet. Inefficiency of feed utilisation may be a result of a low P/E ratio due to (1) an inefficient microbial growth in the rumen through limitation of microbial nutrients in the diet or (2) to a low level of rumen bypass of dietary protein or (3) both. Inefficient utilisation of feed owing to a low P/E ratio may at times result in significant metabolic heat which may embarrass ruminants under high humidity/temperature conditions leading to heat stress which in turn lowers feed intake and results in low productivity.

There is considerable circumstantial evidence that grain based diets fed to cattle may not be used at times as efficiently as possible because of low P/E ratios in the nutrients absorbed. Metabolic heat production in such circumstances could be a factor in severe heat stress of cattle in feed-lots.

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