THE USE OF BYPASS PROTEINS AND NPN IN DIETS HIGH IN SUGAR

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SUMMARY

Sugar based diets for ruminants are now in common use in a number of countries. Research into supplementation of these diets with non-protein and bypass proteins have established a set of guidelines for formulating diets for cattle. The background to the principles involved is discussed and to exemplify these the cattle production systems. based on molasses, sugar cane, derinded sugar cane and sugar cane are discussed.

INTRODUCTION

Ruminant production under tropical conditions has represented a major challenge to the nutritional scientist. In general, the transfer of technology from temperate countries to tropical countries has failed to provide viable ruminant production systems. This has been largely due to the lack of availability of suitable grain crops in the tropics and the rather indigestible nature and low protein contents of tropical as compared to temperate grasses (Minson and Wilson, 1980). The lack of suitable legumes that will persist under grazing in the tropics has also led to low protein grasslands and low animal productivity. The tropics are characterised by pronounced wet and dry seasons and growth of ruminants has followed a yearly rise and fall such that animals are seldom marketable before 6 years of age. The pronounced changes in feed availability and therefore growth rate led to considerable emphasis in research on filling the feed-gap in the dry season. There are four systems for filling the dry season feed-gap. These include (1) conservation of pasture as hay and silage which is difficult because these have to be "made" in the wet season and this has been rather unsuccessful at the farm level. (2) The use of high energy crops with deep roots which maintain their feed quality in the dry season and thereby represent a "living silo" e.g. sugar cane. (3) The storage of high energy agro-industrial by-products such as molasses for use in the dry season. (4) The use of high energy feeds typical of the North American feed-lot rations to finish animals. The latter usually depend on high cost imported grains. Although these systems commenced with the concept of filling the feed-gap in pasture based systems they also have potential for year round production. In addition, the systems. have application for drought feeding of cattle in many regions of Australia.

The development of these feeding systems were dependent on the application of sound nutritional principles. The basal diets all have in common a relatively high energy density and low availability of N. The development of feeding systems based on these feeds by T.R. Preston and his colleagues (see Preston and Leng 1980) has delineated many of the basic principles of diet formulation for ruminants, well before some of these principles were generally applied to ruminant feeding in temperate countries.

In the context of this symposium I will only discuss the role of NPN, and bypass nutrients to balance low protein, high energy diets for high productivity in cattle.

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BACKGROUND AND PRINCIPLES

The desirable characteristics of a basal diet for ruminants is that it provides a readily available fermentable carbohydrate source at low cost and a soluble nitrogen source (usually urea or ammonium salts) which are used efficiently in the rumen, with a relatively high fermentation rate and microbial cell yield.

Having defined the basal diet the next step is to maximise the intake and utilisation of basal diet by supplementation with bypass nutrients, These can be used efficiently since they bypass the rumen, avoiding the energy losses in heat of fermentation and methane, and at times they may also increase feed intake. Where the latter effect is . apparent the supplement can be looked upon as a catalytic supplement. Feed materials should thus be categorised into (a) basal diets and (b) supplements.

The influence of supplements on feed intake of cattle will depend on the primary limiting factor to production on any diet. A supplement may provide a limiting nutrient for either rumen microbes or the animal such as minerals (Na, Ca, P or S for example) or a trace element (Cu, Se, Co etc.), B vitamins (for example niacin has been recently shown to stimulate microbial protein synthesis in cattle (Riddell et al. 1980), essential factors for microbial growth (such as amino acids and precursors of nucleic acids (see Leng 1981) or essential factors which bypass the rumen and which may include vitamins (such as B_{12} which may be marginally deficient or thiamine which is made unavailable in rumen fermentation through bacterial thiaminase activity), minerals (that may be made unavailable by rumen metabolism, such as Mg), essential fatty acids (particularly unsaturated acids that would be saturated in the rumen) or essential amino acids required in amounts greater than produced in rumen fermentation. In addition a supplement may provide essential nutrients to microbes at a continuous slow rate which is 'in step' with the rate of microbial growth. For instance, there is the suggestion from the studies of Oldham (1980) that microbial growth in the rumen of dairy cows on concentrates/roughage diets are stimulated by by a slow release of amino acids which are more efficiently used than ammonia under the prevailing dietary conditions (see Maeng et al. 1976).

There seems to be no doubt that on some diets, supplementation with a protected pure protein (i.e. formal casein) (see Kempton and Leng 1979), or infusion of a protein into the duodenum can give rise to increased intakes of a basal low protein diet (Egan and Moir 1965), . this effect has been demonstrated with low digestibility forages (Hennessy 1981); high digestible diets (Clay and Satter 1979); Ørskov et al. 1973); silages (Gordon 1980); and sugar based diets (Preston and Willis 1974). Under some practical conditions feed intake effects. are not observed to highly protected pure-proteins whereas increases occur to commercially available bypass protein meals based on mixtures of protein meals such as cottonseed, fish meal and/or meat meals.

The major point made here is that there are a large number. of factors that may limit feed intake and production of ruminants on low quality feeds and the effects of supplementation with natural products are therefore seldom predictable and the question is "where responses to bypass proteins do not occur is this because some other essential nutrient is limiting intake?".

Intake of low quality roughages have often been assumed to be limited by bulk-distension of the rumen due to slow breakdown of feed materials 'to sizes which allow them to leave the rumen. However the large increases in intake of basal diets of cows given a bypass protein supplement that have occurred in the studies of Hennessy (1981) on low quality carpet grass (46% DDM) and the smaller increases in feed intake to supplementation with bypass proteins on cereal straws (Leibholtz and Kellaway 1981) indicate that amino acid deficiency is the primary cause of low productivity and that there is great scope for increasing productivity on such diets.

MICROBIAL GROWTH AND REQUIREMENTS FOR N IN THE RUMEN, AND AMINO ACIDS' BY THE ANIMAL

Microbial protein synthesis

The effects in the animal of a greater absorption of essential amino acids from dietary origin will be greatly modified by the net availability of rumen microbial protein to the animal, The amino acid available per unit of organic matter fermented have been measured in a large number of studies and this has varied from about 20-50 g N as microbial protein leaving the rumen per kg of organic matter apparently fermented in the rumen. The dietary carbohydrate, the pH of the rumen and the N source and the microbial species that develop (including protozoa) all appear to affect the efficiency of microbial growth in the rumen (see Leng 1981).

Requirements for fermentable N

A critical feature in the efficiency of microbial growth in the rumen is the availability of rumen ammonia which appears to have to be maintained above 50 mg-N/l at all times for efficient microbial growth (Satter and Slyter 1975). This can be achieved on low protein diets by providing simultaneously with the dry matter at least 30 g soluble-N/kg fermentable organic matter consumed.

Requirements for bypass protein

Ørskov (1970) described the N retention (requirements) of ruminants in relation to growth and physiological state (pregnancy, lactation) of the animal. The potential flow of rumen microbial amino acids, expressed as a contribution relative to energy was then superimposed (see Fig. 1). The obvious deficit of N relative to energy indicated the need for protein of dietary origin which bypassed the rumen. It seems now that in pregnancy, lactation or refeeding following retarded growth that high feed intake and other factors may increase microbial growth substantially. In one trial, with lambs that'had grown at a slow rate for 9 months and were still only 25 kg, growth rates were on average 350 g/d on a diet with a total true protein content of less than 5%. This diet supported growth of less than 200 g/d in previous trials (Leng, R.A., unpublished). Weston (1979) showed that in pregnancy the efficiency of microbial growth increased. The contribution of microbial N is more likely to be that indicated by the broken line in Fig. 1.
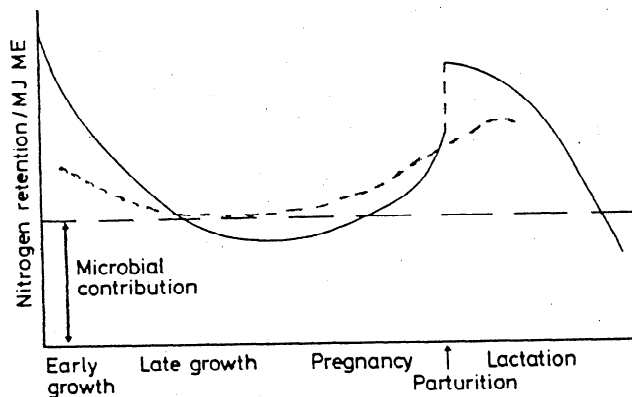
Figure 1   The effect of age and production on potential nitrogen
            retention in relation to ME intake. The concentration of
            microbial N is indicated by the line parallel to the x
            axis (Ørskov 1970). The curved dotted line is suggested
            to be a more likely contribution of microbial N.

PRACTICAL DEVELOPMENT OF FEEDING SYSTEMS

The nature of the new systems of feeding ruminants in the tropics
that have arisen over the past few years have given rise to, or
strengthened many of the basic principles of feeding ruminants. These
diets are based upon high energy crops such as sugar cane or agro- .
industrial byproducts such as molasses. In general to use these diets
efficiently and economically for ruminant production it is necessary,
to: (1) provide the least cost basal diet ad libitum; (2) provide
sufficient N for rumen microbes; (3) provide extra bypass protein to
stimulate intake and production., but where intake has not been
stimulated, to provide bypass nutrients to supply the needs of
pregnancy, lactation and growth; (4) to establish an efficient
rumen function with a high turnover of digesta and a high microbial
output through balancing the amount of fibre to concentrates in the diet
and perhaps chemically manipulating the microbial population.

The systems that best exemplify this approach are cattle
production systems that have been developed on basal diets of molasses,
or sugar cane, derinded sugar cane or sugar cane juice.

Molasses based diets

The use of molasses as a basal diet for cattle arose from studies
in Cuba by Preston and his colleagues (see Preston and Willis 1974). .
In the recent drought in north east Australia it has become firmly
established as a versatile energy source which can provide for
maintenance or growth. The use of molasses based diets exemplifies
the principles to be used to make agro-industrial byproducts into feeds
that will support high levels of growth..

To formulate a diet in which molasses provides a high proportion
of the diet it isnecessary to provide a minimum but restricted roughage
intake (0.8-1.0% of body weight) and sufficient N to supply the ammonia
for rumen fermentation of the sugars (this appears to be about 3% (w/w)
urea in the molasses). On such a diet, weaner cattle will gain 200-400

g/d or cows will maintain body weight. Supplementing this diet
with a highly soluble protein meal (rapeseed meal) has no effect on
feed intake or production but supplying a bypass protein (fish meal)
stimulates intake of molasses and production markedly such that growth
rate approaches 1 kg/d (see Fig. 2, Table 1).

TABLE 1   The effects of rapeseed meal (highly soluble protein) or
           fish meal (a bypass protein) on feed intake and growth of
           bulls given ad libitum molasses (containing 3% urea) and
           1-2 kg of forage (Preston and Molina 1971)

	Supplement	
	450 g fish meal**	785 g rapeseed meal**
Initial weight (kg)	136	135
Final weight (kg)	208	166
Daily gain (kg)	0.85	0.36*
Intake of ME (MJ/d)	9.59	7.0 *
Conversion (MJ/kg)	11.4	20.8 *

* P<0.05
**Solubility of rapeseed meal was 80%, that of fish meal approximately
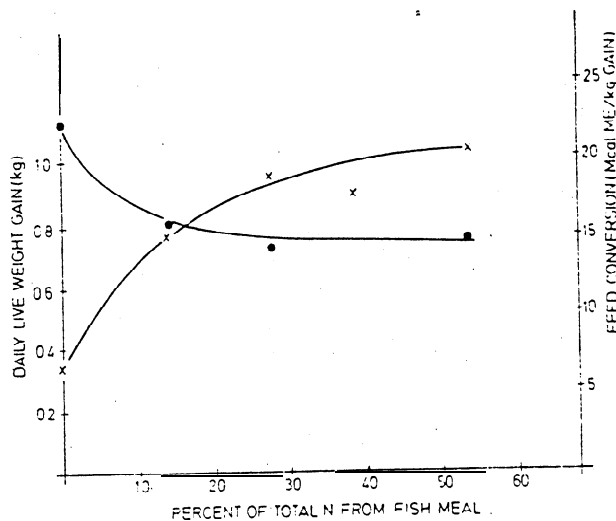 10%.

Figure 2   Effect on gain (x) and conversion (o) of substitution of urea
            by fish meal in molasses-based diets for fattening bulls
            (Preston 1972).

     That these principles are applicable in Australian conditions is
shown by the results of Bird and Leng (1978) and Smith et al (1979)
summarised in Table 2.

     There seems to be little doubt that in cattle on this diet
microbial protein production in the rumen 'is high, since the growth rate
with urea as the sole N sources is substantial. It also is' quite
apparent that availability of dietary amino acids in the rumen does not
stimulate microbial growth (i.e. no response to soluble proteins) but

that dietary amino acids absorbed from the digestive tract stimulate intake of the basal diet.

TABLE 2   Studies in Australia of the effect of bypass protein on feed intake of cattle given ad libitum molasses (containing 3% urea) and 1.5 kg cereal hay

	Supplement	
Experiment 1 (Bird and Leng 1978)	0	240 g protein pellet
Initial weight (kg)	177	180
Final weight (kg)	210	226
Dairy gain (kg/d)	0.47	0.65*
Dry matter intake (kg/d)	3.7	4.2*
Feed conversion ratio (kg DMI/kg growth)	7.9	6.5

	Supplement	
Experiment 2 (Smith et al. 1979)	0	8% fish meal
Initial weight (kg)	161	161
Final weight (kg)	196	224
Daily gain (kg/d)	0.35	0.63*
Dry matter intake (kg/d)	3.9	4.8*
Feed conversion ratio (kg DMI/kg growth)	11.2	7.7*

* $P < 0.05$

Sugar cane based diets

The composition of the dry matter of sugar cane is approximately 50:50 fibre to sugar and as such has more fibre but is similar to the final composition of molasses based diets discussed above. It therefore came as a surprise to find that cattle given sugar cane diets with mineral and urea inputs had poor feed intakes and production, also that responses in feed intake and growth to bypass protein supplementation was very small (see Preston and Leng 1980). Thus there is fundamentaliy something quite different between molasses and sugar cane diets. In search -of a protein supplement Preston et al (1976) showed a linear increase in growth rate in young cattle to supplementation with rice polishing (11% fat, 11% protein, 50% rice starch); Supplementation with 1 kg of rice polishing increased growth rate to almost .1 kg/d. Subsequent studies showed that virtually all the supplement avoided rumen fermentation and a large proportion of the energy was probably absorbed as glucose and fat from the small intestine (Ferreiro et al. 1979; Elliott et al. 1978). This was probably the first demonstration of the important role of bypass energy in promoting production. Later it was shown that similar responses to rice polishings could be obtained with cattle on diets of derinded sugar cane/urea (where fibre was much reduced by mechanically removing the
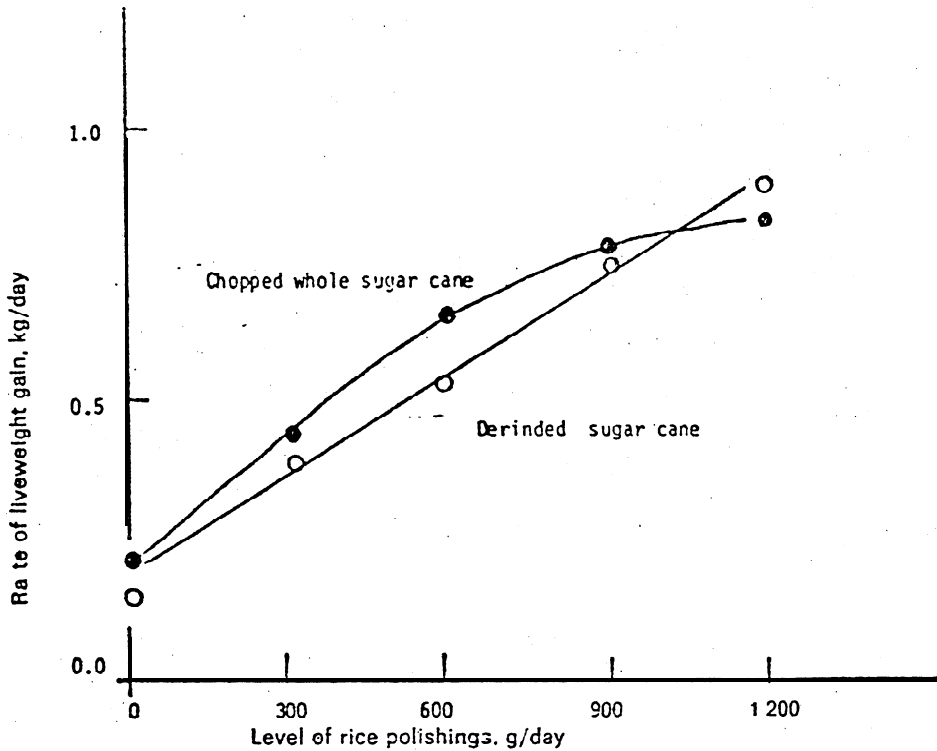
Figure 3   Effect on liveweight gain of level of rice polishings given
            as a supplement to a basal diet of chopped whole or derinded
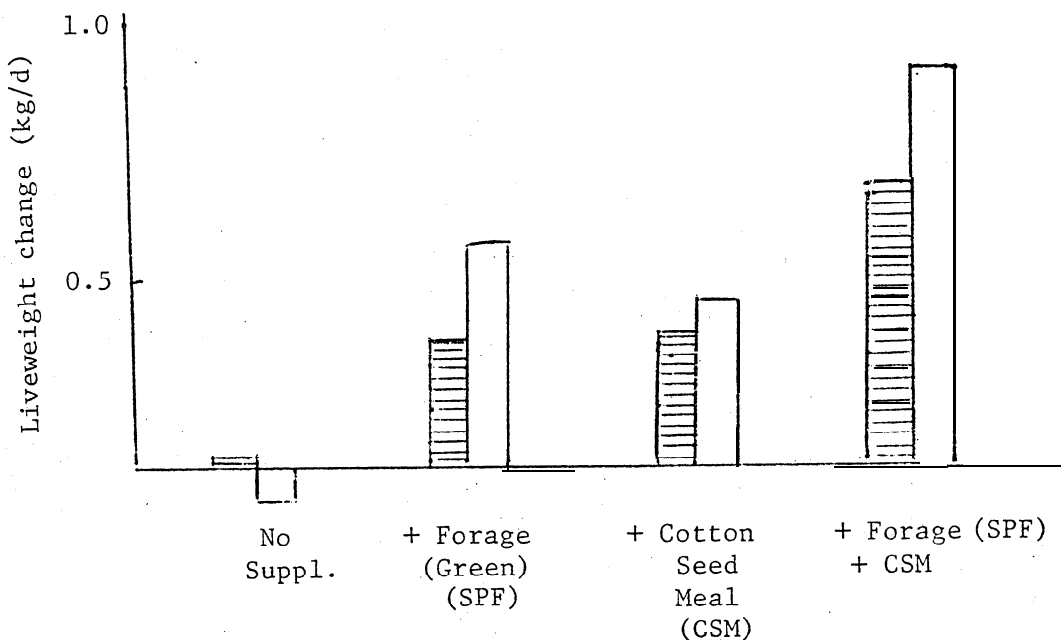   sugar cane (source: Preston et al. 1976).

Figure 4   Cattle growth rates on a basal diet of derinded sugar cane
            supplemented with sweet potato forage (SPF) and/or cotton-
            seed meal (CSM) and two levels of urea (Myreles et al. 1979).
            The unfilled histogram indicates the growth rate at 60 g
            urea/kg dry matter in diet. The filled in histogram
            indicates growth rate at 20 g urea/kg dry matter in diet.

rind)(see 'Fig. 3). However, also on this. diet of derinded sugar cane/ urea responses to both forage and cottonseed meal were recorded (Myreles et al. 1979)(Fig. 4).

The major point here seem to be that a bypass energy source may increase production (without affecting feed intake) to a similar level as that brought about by a 'much' smaller quantity of bypass protein. This poses the question as to whether the extra amino acids from a bypass protein are meeting a requirement for essential amino acids or whether the action of bypass protein is physiological (for instance through hormone effects on feed intake). The effect of supplements on microbial growth, dietary bypass protein and production in cattle on derinded sugar cane diets are shown in Table 3 (after Kempton et al. 1981).

TABLE 3   N utilisation in the rumen, microbial and dietary protein availability and feed intake in cattle given derinded sugar cane/urea diets with or without supplements of sweet potato forage and cottonseed meal (Kempton et al. 1981).

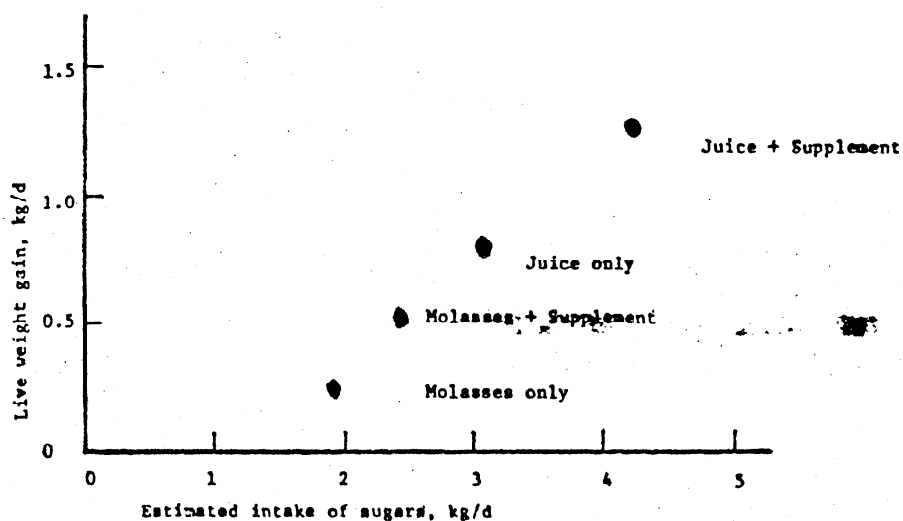|	Derinded sugar cane/urea	Derinded sugar cane/ urea/forage/ cottonseed meal
DM Intake	2.29	5.17
N intake g N/d	63	182
Microbial N flow to duodenum	37	101
Total NAN	54	147
Dietary NAN	17	46
g microbial N/kg fermented DM	28.1	32.4

Figure 5   Relationship between estimated intake of soluble-sugars and rate of liveweight gain on basal diets of molasses or cane juice with or without protein supplement (Sanchez and . Preston, 1980).

Diets based on cane juice

Sugar cane juice has recently been used to provide the energy of a basal diet for cattle. The juice is expressed by passing the cane through rollers. In the initial studies growth rates in cattle on a diet of juice/roughage/urea has been high and intake and production have been increased substantially by supplementation with a protein meal (see 'Fig. 5) (Sanchez and Preston 1980).

CONCLUSIONS

With the exception of whole **sugar** cane there seems to be little' doubt that in the new systems of feeding cattle under tropical conditions where sugar is the major energy component; that bypass protein supplements increase intake of the basal diet and the level of production. The use of bypass energy in such diets is equally effective in increasing production but the stimulation of feed intake is not observed **and larger** quantities of supplements are needed to give an equal response to that of bypass proteins.

The growth rate of cattle on cane and cane-derived diets and the responses which accompanied their supplementation by bypass proteins were greater as the energy density in the dry matter increased, such that the responses to bypass proteins were greatest with cattle on a basal diet of juice, less on molasses and derinded cane and least with whole sugar cane (Fig. 5).

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