

THE INFLUENCE OF BYPASS NUTRIENTS ON GROWTH IN RUMINANTS

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Preamble

In the following paper a deliberately speculative approach has been taken. It was felt that in a symposium that stresses recent advances in nutrition our recent work should be discussed. The majority of the results are preliminary since the studies are as yet incomplete.

Summary

Evidence is presented which suggests that the rumen of sheep and cattle probably provides nutrients at close to maintenance level and that production is considerably increased by the nutrients that bypass fermentation and are digested and absorbed directly.

I. INTRODUCTION

It is generally believed that the amino acid requirements of ruminants are met from two sources, i.e. from microbial protein synthesised in the rumen and digested in the small intestine and from proteins which, because of their physical and chemical characteristics, bypass the rumen and are digested to amino acids which are absorbed from the small intestine (see Kempton, Nolan & Leng 1977; Leng, Kempton & Nolan 1977). The high requirements for glucose in ruminants suggested that part of the apparent amino acid requirements (as indicated by the requirement for dietary bypass proteins) may be a need for amino acids for glucose synthesis. Therefore the provision of glucose for absorption post-ruminally may reduce the need for dietary bypass proteins. This has been discussed in full elsewhere (Leng *et al.* 1977).

Recent data, to be discussed, suggest that the availability of digestible nutrients, in addition to dietary protein, which bypass the rumen may have a major impact on production of ruminants. This suggestion comes from work reported by several groups. Studies with cattle given molasses-based diets have indicated that the major deficiency in the diet is the availability of bypass protein (see Preston & Willis 1970). However, with cattle on diets based on sugar cane, where production is low, responses to bypass proteins are low, but responses to a supplement which provided both starch and protein post-duodenally were considerable (see for review Preston & Leng 1978). Recently Stokes & Thomas (1977) have shown that starch escaping rumen fermentation is a major determinant of efficiency of utilisation of ME for fattening, and Ørskov, Grubb, Webster & Smith (1978) have shown in animals in which the whole diet is supplied by infusions of volatile fatty acids (VFA) into the rumen and protein post-ruminally, that changes the proportions of VFA in the infusate, had little or no effect on the efficiency of utilisation of the metabolisable energy.

In studies in these laboratories it was demonstrated that growth can be increased in lambs on low protein diets if glucose is infused post-ruminally. In recent work, however, where we have examined the interrelationships, similar responses in growth have been obtained to

intraduodenal infusions of equicaloric amounts of acetate, propionate or glucose. Whilst there are indications that glucose plays a most important role in the nutrition of ruminants, these recent results suggest that the all-important role of non protein nutrients which bypass the **rumen** is in providing extra energy for production. The **rumen** appears to be acting in the capacity of a maintenance organ under most situations *i.e.* it provides nutrients at a rate which approximates the maintenance requirements for amino acids and energy nutrients. The work which has led to this conclusion is discussed below.

II. STUDIES WITH CATTLE ON SUGAR CANE AND/OR MOLASSES BASED DIETS

It is now well established that in ruminants on molasses based diets, good responses in feed intake and growth occur to supplementation with dietary bypass proteins and the results of trials carried out by Preston and colleagues in Cuba are shown in Fig. 1.

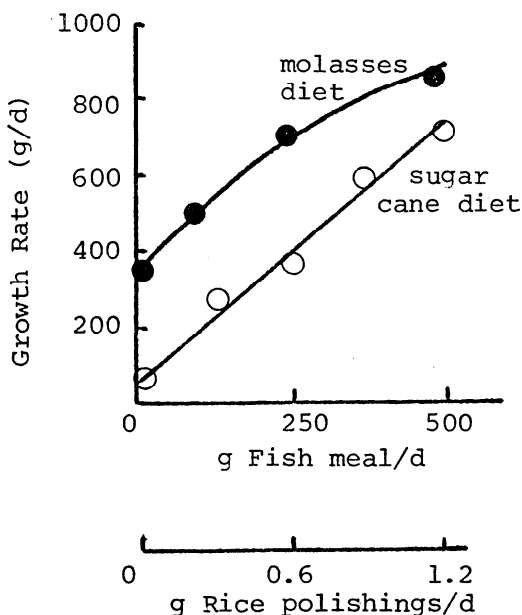


Figure 1. Responses of cattle fed sugar cane or molasses based diets, to rice polishings or fish meal respectively (Preston & Willis 1970; Preston & Leng 1978).

With cattle on sugar cane based diets only small responses occurred to similar inputs of bypass proteins but large responses occurred when rice polishings were included in the diet (see Fig. 1) in which the majority of the digestible energy was in the form of starch. The composition of rice polishings is 10% protein, 11% lipid and 25-40% starch. Results of measurements of glucose entry rates using isotopes (see Ferreiro, Priego, Lopez, Preston & Leng 1979) and with cattle cannulated in the duodenum. (see Elliott, Ferreiro, Priego & Preston 1978) showed that between 50-40% of the starch escaped **rumen** fermentation. In addition almost all the protein was available for intestinal digestion indicating an important role on this diet for bypass nutrients in the form of starch or protein (Elliott, Ferreiro & Priego 1978).

III. STUDIES WITH SHEEP ON SUGAR BASED DIETS

Recent results from these laboratories indicate that there are linear relationships between glucose entry rates (glucose synthesis rates) and production in both cattle and sheep (Kempton & Leng 1979; Smith, Kempton & Leng 1979) (see Fig. 2). Using a modelling approach (Nolan, Rowe & Leng 1979) we have been able to demonstrate that there is also a linear increase in the amount of glucose apparently stored in body tissues as growth rate increases (Leng, Ball, Stachiw & Nolan 1979). Approximately 20 g glucose-C was stored in 200 g of body weight gain in sheep (Fig. 3).

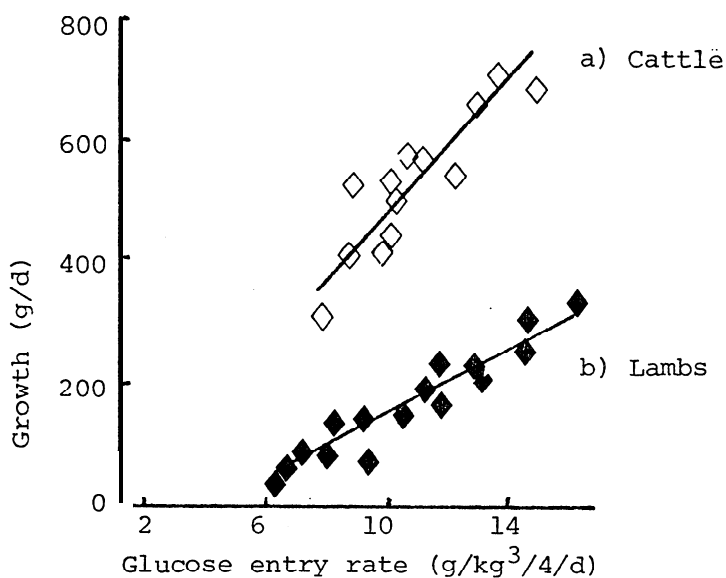


Figure 2. Relationship between glucose entry rate and rate of growth in weaner cattle and lambs.

This indicates the importance of glucose-C in tissue deposition and emphasises the possible importance of dietary bypass starch (i.e. dietary starch leaving the rumen) in increasing production through providing both glucose per se and also in sparing amino acids which might otherwise have been used for glucose synthesis. Studies carried out by Economides, Ball & Leng (1979) indicated that glucose entry rates and growth rates could be stimulated on low protein diets by adding glucose post-ruminally. The results are shown in Table 1. The lambs used in these studies were fed oaten chaff/sugar with minerals, vitamins and urea plus about 6% dietary bypass protein, which is about half optimal requirements for dietary bypass proteins on this diet. Lamb growth was increased by infusing 80 g glucose/d and whilst glucose entry rate increased, urea synthesis rate was decreased. The results indicate that glucose was decreasing amino acid deamination and therefore maybe supplying more essential amino acids for tissue synthesis. In further studies with lambs we have attempted to examine the effect of infusing acetate, propionate, or glucose on the production of lambs on the same diet to attempt to differentiate provision of glucose (or its precursors) or amino acids from the effects of energy per se. The effects of infusing glucose (60 g/d) were similar to previous results in that glucose stimulated growth rates by approximately 20%; however both acetate and propionate (infused in equicaloric amounts) increased growth rates. These studies are at a very early stage and results are not available on

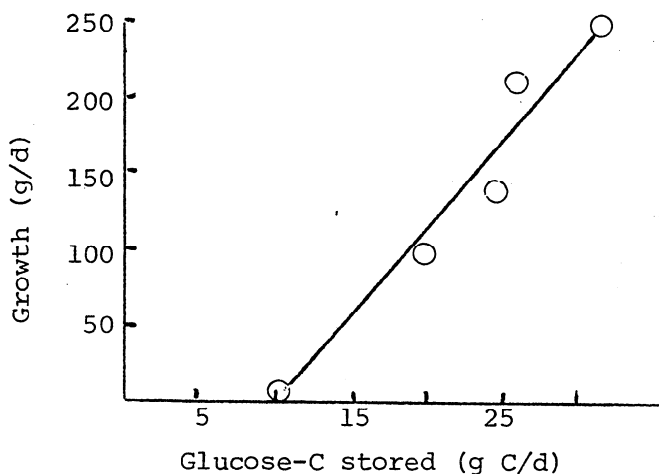


Figure 3. Relationships between growth and glucose-C apparently stored in body tissues (Leng, Ball Stachiw & Nolan 1979) of lambs.

TABLE 1. The effects of glucose infusions (80 g/d) post-ruminally on glucose entry rate, urea entry rate, feed intake and growth of lambs given a diet of sugar/oaten chaff (+ minerals, vitamins and urea) or the same diet supplemented with 6% fish meal. There were 4-6 animals/group) (Economides, Ball & Leng 1979)

Diet *	Feed Intake (g/d)	Growth (g/d)	F.C.R. g feed/g growth	Glucose entry rate (g/d)	Urea entry rate (g C/d)
OO	890 ^a	97 ^a	10.1 ^a	134 ^a	6.2 ^a
GO	770 ^a	129 ^b	6.9 ^b	140 ^a	4.8 ^b
OP	1139 ^b	202 ^c	6.0 ^c	177 ^b	9.0 ^c
GP	1074 ^b	257 ^d	4.3 ^d	224 ^c	8.0 ^d

* Values in columns with different superscripts are significantly different at $P < 0.05$.

OO = basal diet. GO = basal diet + infusion of 80 g glucose/d.
OP = basal diet + 6% fish meal. GP = OP + infusion of 80 g glucose/d.

metabolic parameters that were measured., However it appears that lambs under these conditions had sufficient essential amino acids and glucose precursors to grow 20% faster when infused with energy nutrients and were therefore limited in their growth by the quantities of energy nutrients that become available from the diet.

Recent results by Stokes & Thomas (1977) have supported this concept that the amount of dietary starch that escapes rumen fermentation may be a major factor in productivity of ruminants. The studies of Ørskov et al. (1978) also support this conclusion (see Table 3) since in studies with lambs fed entirely by infusions of protein into the duodenum and VFA into the rumen, and where the proportions of VFA were varied, there was no or little effect on production.

TABLE 2. The effects of infusing equicaloric amounts of glucose (60 g/d) acetate or propionate on feed intake and growth of lambs (6 animals/group). (Leng, Nolan & Kempton, 1978). Lambs were given a diet of oaten chaff:sugar (1:1) plus 4% urea and 6% fish meal and vitamins and minerals. (The results are very recent and have not yet been statistically analysed.)

Infusion *	Feed intake (g/d)	Weight gain (g/d)	F.C.R. (g feed/g gain)
O	742	122	6.2
Glucose	757	168	4.6
Acetate	745	194	4.2
Propionate	688	175	4.2

* Acetate and propionate were infused as sodium salts; the other infusates contained equivalent amounts of Na⁺.

TABLE 3. The efficiency of utilization of VFA as the main source of energy absorbed by ruminants. Lambs were fed by continuous infusion of 1) VFA into the rumen (VFA were infused to give approx. 2 x maintenance energy requirement) and 2) protein into the duodenum. (Taken from Ørskov *et al*, 1978).

Acid proportions in infusate (mM/M)			Efficiency of energy utilisation
Acetic	Propionic	Butyric	
350	550	100	0.75
450	450	100	0.65
550	350	100	0.58
650	250	100	0.61
750	150	100	0.60
850	50	100	0.61

* Protein infused into the duodenum was not given by the authors.

IV. CONCLUSIONS

It appears that if ruminants receive only microbial protein from the rumen to meet their essential amino acid requirements, feed intake is restricted and production is low (or animals are at maintenance) and dietary proteins digested in the small intestine are required to support significant production.

Similarly at any ad libitum intake of a diet, suboptimal in bypass protein (i.e. feed intake is restricted), production may be limited by the availability of energy nutrients, production can be improved by feeding the animal energy sources which bypass the rumen but are digested and absorbed from the small intestine. Under these conditions, dietary bypass energy sources may have little or no effect on feed intake.

Growth of ruminants can therefore be markedly influenced by supplying both bypass protein (which largely stimulates intake) and bypass energy which apparently increases the efficiency of utilisation of available energy and amino acids.

The obvious impact of supplying dietary bypass energy materials can be demonstrated by examining the energy balances in cattle given sugar cane and supplemented with rice polishings (which largely bypasses the rumen) (see Fig. 4).

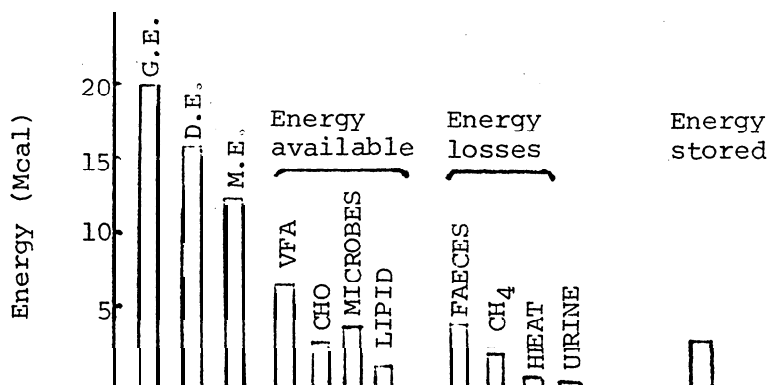


Figure 4. Partitioning of energy in the feed of a bullock given a diet based on sugar cane and supplemented with rice polishings. The energy of carbohydrate and lipid escaping fermentation were assumed to be completely available.

The dietary bypass energy is relatively large in relation to the energy actually stored in body tissues.

The responses to dietary bypass nutrients need to be identified in relation to the ability of these nutrients to supply the requirements for essential amino acids, glucose (or precursors) and energy nutrients. In the experiments we have done the results suggest that at suboptimal protein intakes, the first limitation to growth in lambs is not essential amino acid or glucose supply but energy availability.

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