CHANGING RUMEN FERMENTATION BY CHEMICAL MEANS

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SUMMARY

The manipulation of rumen fermentation is discussed on the basis of the procedures currently available and in terms of the resultant effects on the availability of both protein and energy to the host animal. The use of chemicals to decrease methane loss is compared with those enhancing propionate production. The role of protozoa in the rumen is discussed in relation to their effect on the efficiency of microbial protein synthesis and the metabolisable energy (ME) available to the animal. The control of flow rate and the extent of fermentation in the rumen is also discussed. Reduction in the extent of fermentation in the rumen generally results in increased protein availability but with a decreased supply of ME. By contrast, action of ionophore compounds which decrease the losses of energy associated with fermentation do not appear to reduce the availability of protein.

INTRODUCTION

The processes of fermentation which make ruminant feed utilization much less efficient than is the case with monogastrics have been understood for many years. These are principally associated with heat losses during fermentation, the production of useless high-energy end products such as methane and the unnecessary fermentation of protein and starch. The rate and extent of fermentation of the fibrous carbohydrates are also factors which restrict, the level of ruminant production.

The objectives commonly recognized for improving the efficiency of ruminant production are summarized below.

Decreasing the energy losses during fermentation.

Decreasing the unnecessary fermentation of protein and starch.

Increasing the synthesis of microbial protein.

Optimizing the degradation of fibre in the rumen.

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Although these specific objectives are often considered individually in aiming to optimize the nutrient supply for any production regime, there are in practice a limited number of procedures avail able for modifying the pattern of rumen fermentation and these result in changes to a variety of parameters. In this paper changes to rumen fermentation are discussed under headings describing the procedures available for manipulating the pattern of digestion in terms of the resultant availability of nutrients to the animal. The available ways of manipulating fermentation considered here are(i) the alteration of the pattern of end-product formation using antibiotic compounds; (ii) the removal of protozoa from rumen fluid with surfactant solutions; and (iii) the control of the rumen degradation of dietary protein and carbohydrate by altering microbial activity.

INCREASED PROPIONATE PRODUCTION AND METHANE INHIBITION

The enhancement of propionate production and inhibition of methanogenesis may theoretically improve rumen fermentation efficiency by the same means, i.e. through increased 'hydrogen' utilization in the synthesis of metabolisable end-products,. In two separate experiments the effects of a specific inhibitor of methane production (ICI 111075) (2-trichloromethyl-4-dichloromethenyl-benzo(1,3)dioxin-6-carboxylic acid) (see Stander and Davies (1981) and the propionate enhancer, monensin (Rumensin) were studied.

In the case of ICI 111075 the inhibition of methane production was almost complete, reducing the concentration of methane in the rumen gas phase by 80 per cent. This was associated with a marked rise in the concentration of hydrogen gas from 0.1 per cent of the rumen gas volume to 19 per cent and no significant change in the effective production of rumen VFAs. The effect of the propionate enhancer, monensin, was to significantly increase propionate production and the amount of ME available to the animal as VFA while methane production was reduced to half of the level in the control animals. These data suggest that under the highly reduced conditions in the rumen, the micro-organisms have only a limited capacity to utilise excess metabolic hydrogen which accumulates when methanogenesis is blocked. On the other hand there is good evidence that additional hydrogen utilisation is possible if propionate production is selectively stimulated by an ionophore compound.

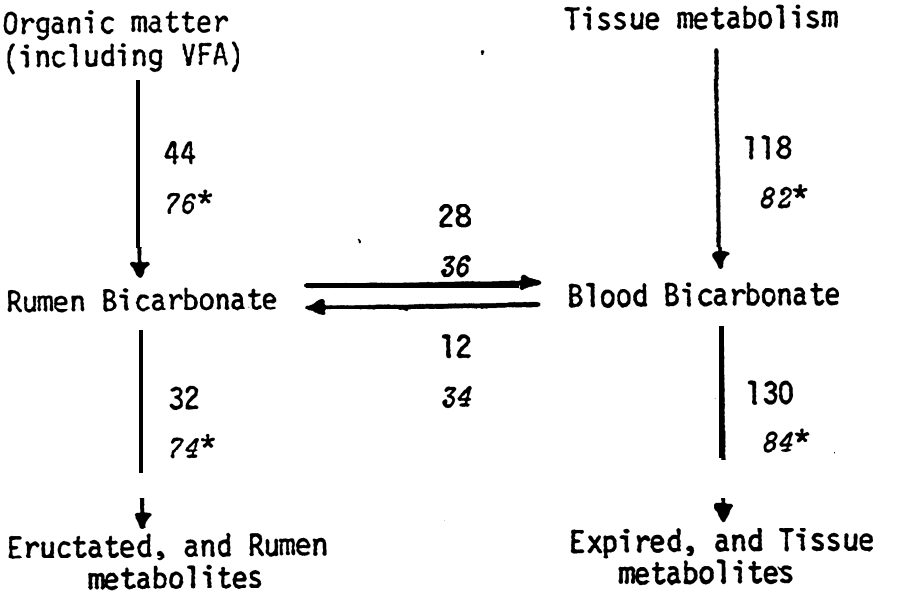
In addition, the amount of methane production when animals are fed high levels of concentrate is comparatively low (Clapp 1982) and any advantage of methane inhibition further reduced. Ionophore compounds appear to improve animal performance over a wide range of diets (see Chalupa 1980).

The effects of ionophore compounds on the nutritional value of feeds, and differences between some propionate enhancers have been discussed previously (Rowe 1983).

IMPROVING THE EFFICIENCY OF MICROBIAL PROTEIN SYNTHESIS THROUGH DEFAUNATION

It has clearly been shown that protozoa in the rumen engulf significant quantities of bacteria (Coleman 1975) and since they do not pass out of the rumen in numbers proportional to their presence in rumen fluid (Weller and Pilgrim 1974) it appears that protozoa may decrease the efficiency with which protein synthesised in the rumen is available to the host animal. Under certain dietary conditions the population of large ciliate protozoa may constitute a significant amount of protein within the rumen (Leng et al. 1981). This population has a slow rate of turnover and since maintenance of the organisms is mainly in the form of ingested bacteria it has been argued that their role may be parasitic - reducing the amount of bacterial protein available to the animal.

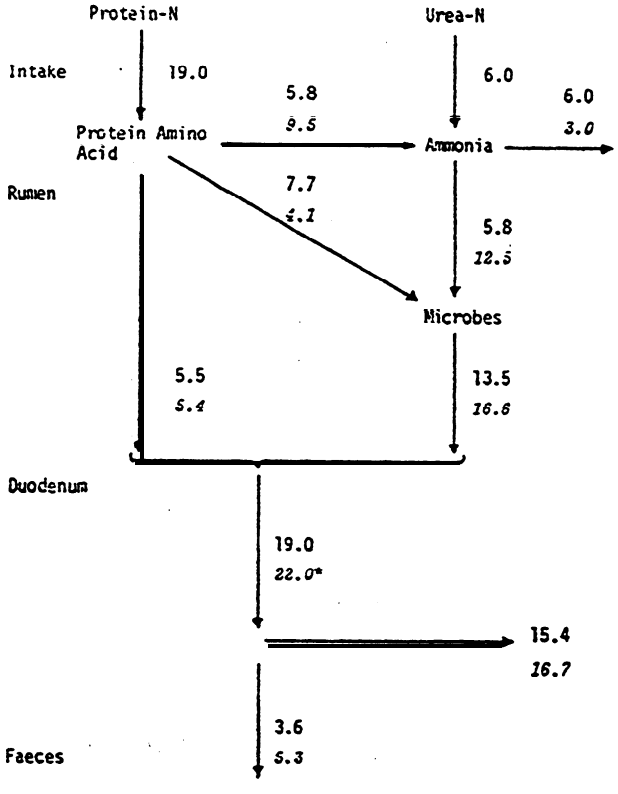
In studies on the effects of defaunation it appears that the amount of protein passing through the small intestine may be increased when protozoa are absent from rumen fluid(Lindsay and Hogan 1972; Rowe et al. 1981).



* Values measured in defaunated animals significantly ($P < 0.05$) different from refaunated sheep.

Fig. 1. Two compartment models describing the production of HCO_3^-/CO_2 carbon in the rumen and by the tissues, measured in animals with refaunated and *defaunated* rumen fluid, The lower figures in *italics* refer to the *defaunated* group. Flows are in g C/d.

However, trials to investigate the responses in animal production to defaunation have produced equivocal results. Only in feeding trials where animals were given diets grossly deficient in protein have positive responses to defaunation been observed (e.g. Bird and Leng 1978). In a recent experiment the role of protozoa was studied in terms of the effects of defaunation on the availability of both protein and ME to the animal (Rowe et al. 1981). In this study measurements were made of the dynamics of nitrogen digestion using ^{15}N as a tracer. The production and interconversion of volatile fatty acids in the rumen and of HCO_3^-/CO_2 in rumen fluid and blood was measured using individual infusions of ^{14}C labelled tracers of each metabolite. One of the most striking observations was the increase in bacterial biomass in the rumen in the absence of protozoa, which appears to be a common result of defaunation irrespective of the basal diet (e.g. Eadie and Gill 1971; Demeyer and Van Nevel 1979). Associated with the high population density of bacteria in defaunated rumen fluid there was a significant increase in the utilisation of volatile fatty acids within the rumen. Although this was predominantly in the form of the interconversion of carbon between acetate and butyrate, there was also significantly more HCO_3^-/CO_2 production indicating increased oxidative fermentation of organic matter within the rumen (see Fig.1). A decrease in the amount of ME available to the animal, as a result of defaunation was further suggested by the reduced production of HCO_3^-/CO_2 by the tissue of the defaunated animals.



* Significantly (P = 0.06) different from refaunated animals.

Fig. 2. N flows measured in animals with refaunated and *defaunated* rumen fluid. The lower figures, in *italics*, refer to the *defaunated* group. Flows are in g N/d.

The measurements of nitrogen digestion and metabolism are summarised diagrammatically in Fig.2. The apparent increase in the amount of protein entering the small intestine was associated with increased microbial protein 1 eaving the rumen. The higher loss of nitrogen *in* the faeces probably indicates a lower digestibility of the bacterial organic matter in the intestines which would result in a higher level of faecal fermentation and increased excretion of microbial protein.

The results of this study indicate that while removal of protozoa from the rumen does appear to increase the amount of microbial protein available to the animal it may also result in a decreased supply of ME. This may explain why on diets high in ME and with a low protein concentration the effect of defaunation may be beneficial in reducing the ratio of ME to protein and providing the animal with a more balanced supply of nutrients. In dietary situations where sufficient protein is available any decrease in the amount of ME would be expected to reduce the level of animal production.

CONTROL OF FLOW RATE AND THE EXTENT OF FERMENTATION IN THE RUMEN

The extent of fermentation of dietary substrate in the rumen may be controlled by altering the time which the feed is present in the rumen and also by treatment of the feed itself to change the rate of fermentation. These factors are summarized in Figure 3.

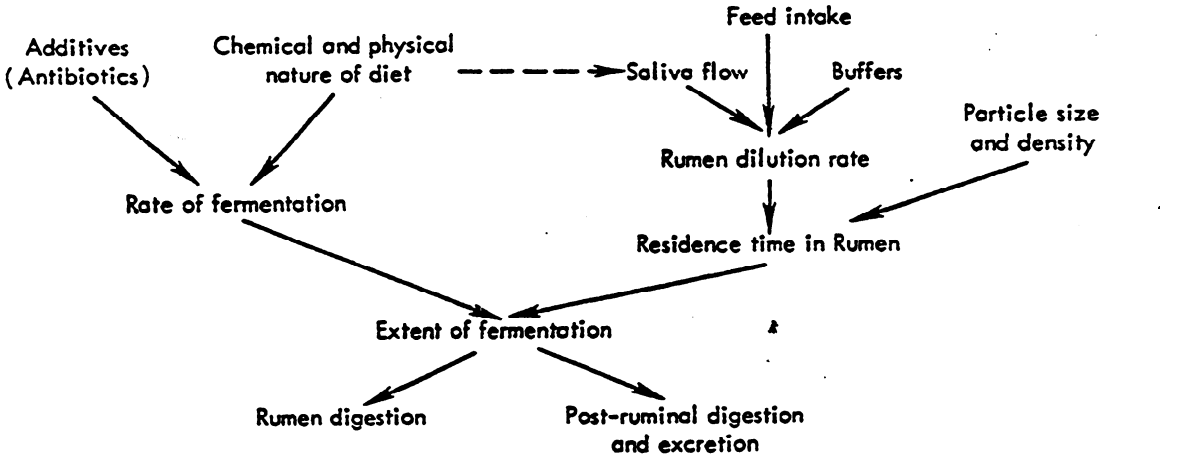


Fig. 3. Diagrammatic summary of factors affecting the site of digestion in ruminants.

Al though chemical treatment of the feed (e.g. alkali treatment of straw), alteration of the physical form of the diet by grinding and pelleting (see Beever et al. 1981) and the use of buffers to affect dilution rate (e.g. Rogers et al. 1982) are all effective ways of improving the efficiency of feed utilization their usefulness under field conditions is limited by cost and logistics. For this reason, the alternative approach of controlling fermentation through antibiotic manipulation of the rumen micro-organisms is most attractive.

Recently, the glycolipid antibiotic flavomycin was released as a growth promotor for use in ruminant animals on the basis of its effect in increasing cellulase activity (Hoechst, unpublished). Increased growth rates between 5 and 10 per cent were observed in a number of cattle trials, and these gains were associated with small improvements in feed conversion efficiency (Hoechst, unpublished).

In an experiment to further investigate the effect of flavomycin on fibre degradation in the rumen (Rowe et al. 1982), nine cattle with rumen cannulae were fed a basal diet of barley-based concentrate (1.2 per cent of liveweight/d) and hay ad libitum. There were three dietary treatments (3 animals/treatment): control; and either flavomycin or monensin added to the concentrate to provide 0.2 and 0.5mg/kg liveweight per day respectively). Samples of chopped hay were suspended in the rumen in dacron bags for 24 hours. Samples of rumen fluid were also taken for analysis of volatile fatty acid and ammonia concentrations. The results are summarized in Table 1. There was no evidence of increased fibre degradation rate and no changes were measured in the concentrations of any of the rumen metabolites associated with the use of flavomycin. The effect of monensin on rumen fermentation were to decrease fibre digestion and to increase the concentration of propionate.

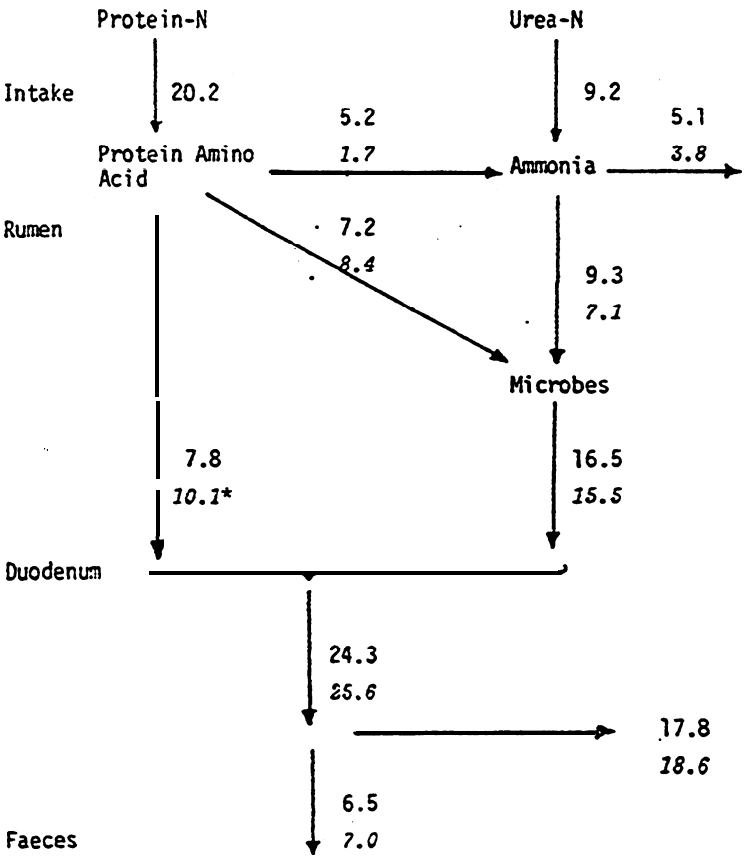
Antibiotic treatment	Daily Dose (mg/kg liveweight)	Fibre degradation	Proportion of propionate
Monensin	0.5	86*	115*
Flavomycin	0.2	101	102

* Significantly (P 0.05) different from 100 percent.

Table 1. The effect of flavomycin and monensin on the rate of fibre degradation and the molar proportion of propionate. Values are given as percentages relative to control (100 percent).

It appears therefore that although the concept of improved bacterial efficiency of cellulolysis is still attractive there is as yet no artificial means of stimulating this process.

Decreasing the amount of ruminal degradation of dietary protein through manipulation of microbial fermentation in the rumen has also been the subject of extensive research. Several groups of compounds have been shown to decrease protein hydrolysis and ammonia production in vitro (e.g. diary1 iodenium compounds) but none are commercially available. In addition to evidence of an increased flow of starch from the forestomachs when an ionophore (monensin) is given with a maize-based diet (Muntifering et al. 1981) it appears that the extent of protein degradation may also be reduced. In an experiment where sheep were given a diet of concentrate and hay containing either no medication or ICI 139603 to supply 0.4mg/kg liveweight per day (see Rowe et al, 1983), N digestion was measured from an infusion of ^{15}N ammonia into the rumen. The results of this study are summarized diagrammatically in Fig. 4.



* Significantly ($P < 0.05$) different from animals given the control diet.

Fig. 4. N flows measured in animals fed a control diet or one containing the *propionate enhancer ICI 139603*. The lower figures, in *italics*, refer to animals given ICI 139603.

Although there was a decrease in the degradation of dietary protein there was not a significant depression of microbial protein synthesis. This action of ionophore compounds could have important application in animal production systems where responses to supplementation with a high quality protein are expected.

CONCLUSIONS

Processes of feed treatment which decrease the extent of fermentation in the rumen as well as those designed to increase the protein available to the animal (e.g. defaunation) generally appear to result in a reduced supply of ME. In most feeding systems the price paid for dietary sources of digestible energy are a primary consideration. Under these conditions the availability of additional protein at the expense of reduced ME may not be desirable.

By contrast, chemical manipulators such as the ionophores are most successful in reducing the losses of energy associated with rumen fermentation.

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