PROTEIN SYNTHESIS IN THE RUMEN OF BULLS GIVEN DIFFERENT LEVELS OF MOLASSES AND CASSAVA ROOT

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Three bulls (Zebu x Holstein) fitted with permanent cannuale in the rumen and in the duodenum were used to estimate the efficiency of microbial protein synthesis in the rumen, when the dietary carbohydrate consisted of different proportions of sugar (molasses) and starch (cassava root). Freshly chopped cassava forage was given each day as a source of roughage and protein .

The flow of digesta through the duodenum and the faecal output were estimated using the inert marker Cr_2O_3. A maximum possible value for the synthesis of microbial protein was estimated from the flow of crude protein to the duodenum. The apparent fermentation of starch in the forestomachs was 94 + 2% of that consumed, and was not affected by the level of intake of starch. There were no effects of the level of intake of cassava root on the apparent DM digestibility of the ration across the forestomachs or the whole digestive tract. The values for these two parameters were 67 + 22 and 81 + 2% respectively. Assuming that the amount of dietary non-ammonia Npasaing to the duodenum was the same for all diets the maximum efficiency of microbial protein synthesis (g duodenal crude protein/lOOg DM fermented in forestomachs) was estimated This value varied from 4.3 to 12.8 and appeared to be positively related ($r^2 = 0.62$) to proportion of fermentable substrate in the ration provided by starch. It wee suggested that the low apparent efficiency of microbial protein synthesis was due to the discontinuous supply of fermentable substrate to the rumen micro-organisms when molasses was the main component of the diet, and that the improvement in efficiency observed when increasing amounts of starch were given was a result of a more even distribution of substrate with time.

Key words: Cattle, molasses, starch, protein synthesis

When diets based on molasses, urea and a low quality forage source are given to ruminants, it appears that the first limiting nutrient is protein (Preston 1972). In view of the widespread use of this basic diet and the high cost of providing a protein meal supplement, the amount of protein that can be synthesized in the rumen under these conditions is of importance.

Forrest and Walker (1971) suggested that the energetic efficiency of microbial cell synthesis was close to optimal when sugars provided the main substrate for growth. However, it has recently been shown , in an experiment with sheep, that the synthesis of microbial protein was more efficient when starch was compared with sugar, as the main dietary source of fermentable carbohydrate (Offer et al 1978).

In this experiment different levels of soluble sugars and of starch were given to three bulls by altering the proportions of molasses and cassava root in the ration. The effect of the different sources of carbohydrate on the efficiency of protein synthesis in the rumen was measured by estimating the disappearance of DM in the forestomachs and the flow of N to the duodenum. Cassava root was chosen as the source of starch, since it has been shown to be extensively fermented in the rumen (Santana and Hovell 1979).

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Materials and Methods

Animals, diets ! and design: : Three crossbred (Zebu x Holstein) bulls fitted with permanent cannulae in the rumen and in the duodenum (single "T-shaped" cannulae, approximately 5 cm from the pyloric sphincter) were used. The animals weighing between 210 and 230 kg (approximately 2 years of age) were housed under cover in single stalls on a concrete floor. The experimental design was a 3 x 3 Latin square, with periods of 21 d. The three rations and their composition of DM, starch and N are shown in Table 1. The sun-dried cassava root was prepared by grinding in a hammer mill and was fed mixed with the forage. The forage was harvested each day and then chopped in a stationary forage harvester . The molasses/urea solution was fed in a separate trough. Feed refusals were weighed each morning immediately before feeding. Samples of the feed were taken during each period -to estimate DM, N and starch.

Table 1:
The composition of each experimental ration and of the dietary constituents

Ingredient	Amount offered (kg fresh material/d)			%DM	g/100g DM	
	High Starch	Medium Starch	Low Starch		Starch	N
Molasses/urea	3.0	3.5	4.0	69	-	1.6
Cassava root	1.5	1.0	0.5	94	73	-
Cassava forage	5.0	5.0	5.0	22	-	2.7

Procedure: The methods used for estimating the flow of DM, N and starch to the duodenum, and of faecal DM output, were identical to those described previously (Rowe et al 1979a). Briefly, Cr_2O_3 was used as a marker of digesta DM and was injected into the rumen at 8 hr intervals for 7 days. During the last 24 hours samples of duodenal digesta were taken each hour and bulked to form a single sample which was analysed for $_{Cr2O3}$. During the third period animal 1 consumed only a very small amount of feed and was removed from the experiment and no data were collected.

Results

The levels of intake of the different dietary constituents and the flow of DM through the digestive tract are given in Table 2, for the individual animals in each period. In situations where not all of the mixture of cassava forage and root was consumed , it was assumed that the refusal of each component was in proportion to the amount in which it was given in the ration. The mean apparent digestibility of all rations was 70 + 2% across the forestomachs and 81 + 2% in the whole digestive tract.

The intake of N and starch is given in Table 3 together with their rate of flow to the duodenum and the efficiency of microbial protein synthesis, estimated in terms of the crude protein flowing to the duodenum per 100 g DM disappearing in the forestomachs.

Table 2:
Intake of dietary constituents and the digestion of DM in the forestomachs and in the whole digestive tract.

	Low starch			Medium starch			High Starch	
	Animal			Animal			Animal	
	1	2	3	1	2	3	2	3
Intake kg/d								
Molasses/urea	4.0	4.0	4.0	3.5	3 5	3.5	3.0	3.0
Cassava root	0.5	0.3	0.4	1.0	1.0	0.9	1.1	1.5
Cassava forage	5.0	2.7	4.0	5.0	5.0	4.7	3.8	5.0
DM digestion kg/d								
Intake	4.46	3.73	4.13	4.56	4.56	4.41	4.04	4.67
Duodenal flow	1.17	0.99	0.92	1.63	1.79	1.28	1.56	1.19
Faecal output	0.89	0.44	0.82	1.25	0.82	0.77	0.93	0.77
Apparent digestibility %								
Forestomachs	73.7	73.5	77.7	64.2	60.7	71.0	61.4	74.5
Whole tract	80.0	88.2	80.2	72.6	82.0	82.5	77.0	83.5

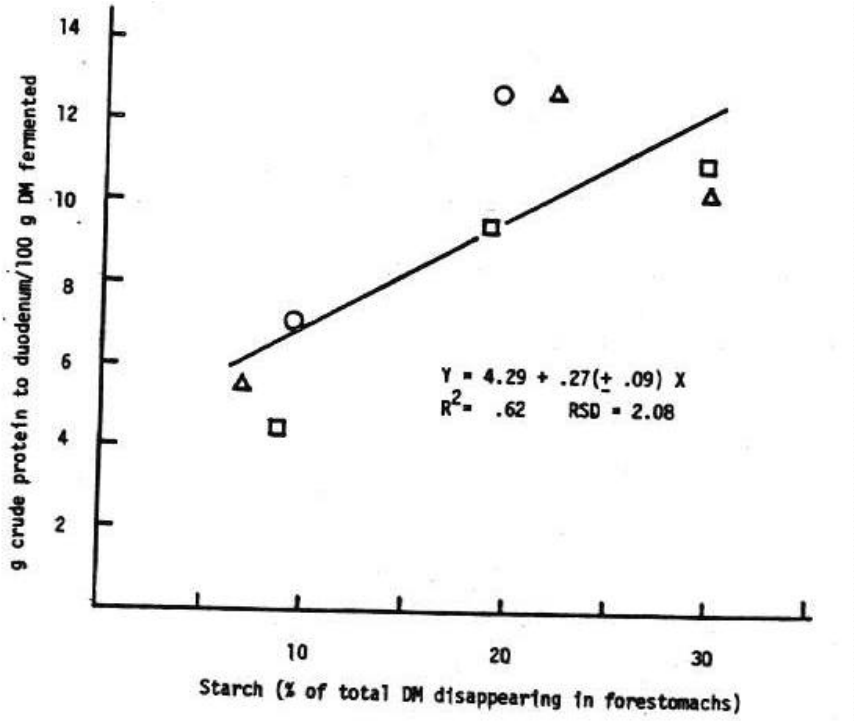
Table 3:
Intake of starch, the flow of starch and N to the duodenum, and the efficiency of protein synthesis in the forestomachs.

	Low starch			Medium starch			High Starch	
	Animal			Animal			Animal	
	1	2	3	1	2	3	2	3
Intake of starch g/d	340	200	270	680	680	630	770	1030
Duodenal flow	.							
g starch/d	26	5	6	107	61	34	20	22
N/d	37	27	22	60	57	46	42	61
Microbial protein synthesis[1]	7.1	6.1	4.3	12.8	12.8	9.2	10.6	11.0

[1] g crude protein (N x 6.25)/100 g DM apparently fermented

In the range of DM intakes observed in this experiment, and within the accuracy of the technique used to estimate the flow of material to the duodenum, there was no effect observed on the flow of N to the duodenum in response to variation in the amount of DM disappearing in the forestomachs. However, there appeared to be an increase in the efficiency of microbial protein synthesis as the proportion of starch, in the total DM disappearing in the forestomachs, increased. This is seen graphically in Figure 1. In the same way there appeared to be an increase in the flow of N to the duodenum when more starch was consumed and conversely a decrease in the flow of N when the proportion of molasses in the ration increased.

Figure 1:
The relationship between the efficiency of microbial protein synthesis and the proportion of starch of the the total DM disappearing in the forestomachs.
Animal 1(◦); Animal 2(△); Animal 3 (□)



Discussion

The results of this experiment indicate the same trend reported by Offer et al (1978). That is starch appeared to act as a substrate which supported a more efficient microbial cell synthesis rate than did soluble sugars. The efficiency of microbial protein synthesis has to be estimated on the basis of all duodenal N being of microbial origin. This simplified method of estimation provides a maximum possible value for the synthesis of microbial protein, since there may also be N present as NH_3, from endogenous secretions and also of dietary origin, included in the total N Kjeldahl

analysis. The NH_3 may represent 4 - 6% of total duodenal N (Nolan 1975; Cole et al 1976) and since it is normally lost during drying (Prigge et al 1978) it was not considered to be a major source of error. All diets contained the same amount of protein and it was assumed that the amount of dietary protein passing undegraded from the rumen was relatively constant during this experiment, and that variation in the flow of N to the duodenum was due to differences in the quantity of microbial protein synthesised in the rumen.

It is important to note that the efficiency of microbial synthesis observed throughout this experiment was low in comparison with values reported in the literature (eg Isaacson et al 1975). The maximum efficiencies observed here (12.8 g crude protein/100 g DM disappearing) were close to those observed by Hume (1970) for a protein free diet (13.3 g protein/100 g OM fermented). However in the diets fed in this experiment cassava forage was given, and this supplied about 140 g crude protein/d Although the turnover rate of rumen fluid was not measured in this experiment; in cattle given a similar diet the turnover rate was approximately 1.5 volumes/d (Rowe and Encarnacion , unpublished observation). This is slightly higher than the turnover rate reported by Hume (1970) for sheep given a protein-free diet, and it therefore appears that the low efficiency of microbial cell synthesis is not due to a low rate of fluid turnover, or to an absence of dietary protein,

The sludge type of secondary fermentation found in the rumen of a sheep given a molasses - based diet(Rowe et al 1979b) could also be present in the rumen of these molasses fed cattle. The bacteria that appeared to be associated with this type of fermentation were predominantly window pane sarcina, which were previously isolated from marine mud (Stadtman and Barker 1951). Organisms that are suited to this poorly mixed sludge-type environment would not be expected to be characterized by very rapid growth rates, and efficient molar cell yields.

Cattle given free access to molasses consume a number of small meals throughout each 24 hour period, instead of the 1 or 2 major feeds that animals have when given free access to forage based rations. However the rate at which soluble carbohydrate is fermented in the rumen ($T_{1/2}$ approx 3 min: Marty and Sutherland 1970), is very much more rapid than that of the succulent leaves of cassava forage ($T_{1/2}$ approx 13 hr; Minor and Hovell 1979). Therefore when molasses is the main source of fermentable organic matter in the diet there may be long periods when the availability of substrate for rumen microbes is very low. Under these conditions, bacteria with slow growth rates and/or the ability to use the end products of the primary carbohydrate fermentation (eg VFA) for growth and maintenance, may have a competitive advantage over the more rapidly growing organisms. In this way, the inclusion of a source of starch in a molasses based diet ($T_{1/2}$ approx 10 hr; Santana and Hovell 1979)may improve the efficiency of protein synthesis by providing a more uniform supply of fermentable energy for the rumen bacteria, favouring those organisms characterised by a continual and rapid rate of growth.

Further studies are required to investigate the exact manner by which the supply of starch as a source of carbohydrate increases the efficiency of microbial protein synthesis, and to find means of improving the efficiency of microbial cell synthesis in cattle given molasses based diets. It is also possible that the efficiency of microbial synthesis could have

been increased by feeding the dietary sources of energy (cassava root) and protein (cassava forage), mixed together, and thus providing a simultaneous supply of energy and protein for microbial growth (See Henderickx and Martin 1963).

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