

RICE POLISHINGS AS A SUPPLEMENT IN SUGAR CANE DIETS: THE QUANTITIES OF STARCH (α -LINKED GLUCOSE POLYMERS) ENTERING THE PROXIMAL DUODENUM¹

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3 Zebu cross steers each fitted with a permanent rumen fistula and a T piece cannula in the proximal duodenum, were used in a 3 x 3 Latin square design experiment to determine the quantities of alpha linked glucose polymers entering the small intestine, when fed a diet of chopped sugar cane plus 1 kg/d of molasses containing 30 g urea/ kg with levels of rice polishings of 0.4, 0.8 and 1.2 kg/d. Each experimental period lasted for 3 weeks, at the end of which rumen dilution rates and duodenal dry matter flows (kg/24 hr) were measured using polyethylene glycol and chromium-EDTA respectively. Rumen ammonia-N levels were low at all times throughout the experiment and there were no significant differences between treatments. There was a tendency to increase both rumen turnover and outflow with increased quantities of supplement in the diet. Values for rumen turnover were 1.36, 1.51 and 1.99, and rumen outflow (litres/ day) 82, 115 and 123, corresponding to levels of supplementation of 0.4, 0.8 and 1.2 kg/d. No significant differences were found in the quantities of dry matter, organic matter and total nitrogen entering the small intestine (g/24 hr) due to the level of supplement in the feed. There were however significant between treatment differences in both the concentration (g/100 g DM) and quantity (g/24 hr) of alpha linked polymers entering the small intestine due to the level of rice polishings in the diet. Increasing the level of supplementation from 0.4, 0.8 to 1.2 kg/d resulted in increased concentration of the alpha linked polymers in the duodenal digesta viz 9.7, 13.1 and 20.0 (g/100 g DM). Corresponding quantities per 24 hr were 288, 464 and 765.

Key Words: Cattle, sugar cane, rice polishings, rumen turnover, duodenal cannulas, starch passage

Supplements of rice polishings have consistently resulted in improved live weight gain of cattle fed basal diets of chopped sugar cane (Preston et al 1976; Lopez & Preston 1977). It has been postulated (see Leng and Preston 1976) that this effect could be due to large quantities of starch and or protein from the supplement escaping degradation in the rumen. In a number of studies, however, some commercial protein sources known to be resistant to ruminal degradation but with no starch content (e.g. meat meal) have not produced the production responses obtained with rice polishings (Preston and Bonaspetti 1975; Silvestre et al 1977ab). The needs for glucose and/or gluconeogenic precursors in animals fed sugar cane diets have been discussed by Leng and Preston (1976). The purpose of the experiment reported here was to test the hypothesis that substantial quantities of starch (as α -linked glucose polymers) pass into the proximal duodenum of cattle when rice polishings are fed as a supplement to sugar cane.

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Materials and Methods

Animals: 3 Zebu cross steers were used in a 3 x 3 Latin square design experiment. Each animal had a permanent fistula in the rumen and proximal duodenum. The duodenal cannula consisted of a rigid plastic T piece, which projected approximately 5 cm from the side of the animal. The animals were individually penned and fed. They had free access to fresh water at all times. A mineral mixture containing all the major minerals and trace elements was fed with the rice polishings at the morning feed.

Treatments: These were levels of rice polishings of 0.4, 0.8 and 1.2 kg/d.

Diets: Diets consisted of chopped whole sugar cane given ad libitum, 1.5 kg/d of molasses/urea (20 urea, 20 water, 960 molasses w/w), the different levels of rice polishings and 50 g/d of a mixture of salt, dicalcium phosphate and trace elements (50, 35, 15 w/w).

Rumen dilution and outflow: A solution containing 76 g polyethylene glycol (PEG) was introduced into the rumen of each animal at the end of each experimental period. This took place at 8.00 a.m. just before the morning feed. Rumen samples were taken subsequently at intervals over the next 24 hr (see Priego et al 1977 for details of analytical procedures).

DM flow into the proximal duodenum during a 24 hr period: For one week before the collection of duodenal digesta in each experimental period, one litre of a Cr-EDIA solution (Binnerts et al 1968) was infused into the rumen of each animal: 500 ml was given at the time of the morning feed and 500 ml at the afternoon feed. The Cr-EDTA solution was made by mixing a solution containing 14.2 g of $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ in 200 ml of glass distilled water with a solution containing 20g Na-EDTA in 300 ml of water. The composite solution was boiled slowly for 1 hr and allowed to cool before being made up to one litre.

Twenty-four hr after the collection of rumen samples for PEG determination the collection of duodenal digesta commenced. The following collection procedure was used to obtain a representative sample. The animals were tied to the feeding trough at the time of the morning feed and a length of flexible plastic tubing was introduced into the protruding duodenal cannula. The issuing flow of digesta was collected in a bucket for one hr. At the end of this period, the tube was removed from the cannula and the animal allowed to rest for one hr. The animal was then subjected to another collection period of one hr duration. This series of alternating procedures lasted for 24 hr. The quantities of each collection period were weighed, homogenised and a 10% subsample stored at 2°.

Rumen pH and ammonia-N: 10 ml of rumen liquor were taken from each animal at the end of each hourly sampling period during the duodenal collection and the pH determined. To this sample 10 ml of 2M HCl was added and the sample maintained at -5° until analysed.

Sample preparation: The bulked 10% samples of duodenal digesta from each animal were homogenised and a sub-sample (approx 500 ml) dried in an aluminium foil dish at 80°. The dried material was then removed from the dish and reduced to a fine powder in a molar and pestle.

Analysis: All samples were dried to constant weight at 103° to determine the DM percentage; the dry material was subsequently ashed in a muffle furnace at 550° to determine the OM fraction. The chromium determination was that reported by Stevens and de Langen (1960). PEG was determined by the method outlined by Priego et al (1977). Nitrogen was determined by the standard Kjeldahl procedure. NH₃-N in rumen liquor was estimated by distilling 10 ml of the rumen fluid/HCl mixture with 10 ml of a saturated sodium tetraborate solution and collecting the evolved ammonia in the indicator trapping solution used for total-N determinations. The method chosen for analysis of alpha-linked glucose polymers in duodenal digesta was that of MacRae and Armstrong (1968) using the enzyme preparation "AGIDEX" (Glaxo Ltd, England) to produce glucose which was measured using the Boehringer glucose estimation kit (Boehring Mannheim West Germany).

Results

The results are given in tables 1 and 2.

Rumen pH and ammonia: There were no significant differences due to level of rice polishings.

Rumen turnover outflow and volume: Although the differences between treatments were not significant there was a tendency for both rumen outflow and turnover rate to increase with the level of rice polishings in the diet.

Duodenal parameters: The DM flow rates (kg/24 hr) were adjusted to give 100% recovery of chromium. There were no significant differences between treatments in any of the parameters measured, although there was a tendency for total-N flow at the duodenum to increase with increasing levels of supplement in the diet. One particularly noticeable feature was the large capture of total-N in the rumen on all treatments, resulting in a greater quantity of total-N passing at the proximal duodenum than was present in the feed.

Table 1:

Mean daily intakes of dry matter (DM), organic matter (OM) and total nitrogen (N) for bulls fed sugar cane, molasses/urea and rice polishings

	Level of rice polishings, g/d			SE _x
	400	800	1200	
DM intake kg/d				
Sugar cane	5.1	5.7	5.7	.08
Molasses/urea	1.5	1.5	1.5	
Minerals ¹	.05	.05	.05	
Rice polishings	.40	.80	1.20	
Total DM, kg/d	7.05	8.05	8.45	
Consumption index ²	2.27	2.49	2.69	.01
Total OM, kg/d	3.76	3.98	4.61	.03
Total N, g/d	390	460	550	

¹ Mineral mixture containing salt, dicalcium phosphate and trace elements

² Kg DM/100 kg LW

Table 2:

Mean values for rumen and duodenal parameters in 3 steers given a basal chopped sugar cane, molasses/urea diet, supplemented with different levels of rice polishing

	Level of rice polishings, g/d			SE _x
	400	800	1200	
Rumen parameters				
pH	6.5	6.7	6.7	.04
NH ₃ -N,mg/100 ml	4.9	4.5	4.2	.58
Fluid volume, litres	63.3	75.5	68.8	11.1
Turnover rate/24 hr	1.36	1.51	1.90	.22
Flow rate, litres/24 hr	81.7	115.5	123.2	12.6
Duodenal parameters				
DM flow, kg/24 hr	2.96	3.61	3.28	1.2
OM flow, kg/24 hr	2.31	3.07	2.63	.84
Total N, g/24 hr	80	103	127	4.0
α -linked glucose polymers				
Concentration, g/100 g DM	9.7	13.1	20.0	1.76
Flow, g/24 hr	288	464	765	36

The concentration of alpha-linked glucose polymers (g/100 g DMg in the duodenal digesta showed substantial increases according to the level of rice polishings; and this was reflected in the quantities entering the duodenum which increased from 288 g/d on 400 g/d of rice polishings to 765 g/d when 1200 g of rice polishings were given.

Discussion

The results show quite clearly that a considerable amount of the alpha linked glucose polymers provided by the rice polishings escaped rumen degradation and reached the proximal duodenum. Indeed, this was clearly evident when the vessels used to collect the bulked-duodenal digesta were inspected at the end of the collection period. The rice polishings formed a thick white layer at the bottom of the flasks. It is also interesting to note that the greater part of this sediment was comprised of the broken tips of the rice grains.

Doubt can certainly be cast on the absolute values of duodenal flow rates determined with surgically modified animals. Nevertheless the results for concentration of alpha-linked glucose polymers in duodenal digesta demonstrate quite conclusively that considerable amounts of starch did enter the duodenum. That the rice polishings do escape degradation was established by slaughter experiments (Minor et al 1977). However, the levels reported here were unexpectedly high. Elliot and Carpenter (1976) studied passage of starch sources from the rumen of dairy cows fed 5 to 12 kg/day of starch.

They found that from 0.5 to 2 kg/d entered the abomasum. They also reported

that the ability of the animals duodenal carbohydrases and glucose absorption mechanisms were frequently exceeded and starch appeared in the faeces. This observation was also noted in the present experiment when undigested rice grain tips were frequently observed in the faeces.

It could be argued that in this experiment the levels of ammonia-N in the rumen were too low to permit maximum microbial protein synthesis, and this may have affected the quantity of energy digested in the rumen (Buttery and Annison 1972; Allen and Miller 1972). However, Hume et al (1970) fed sheep a series of purified diets containing 0.5, 0.95, 1.82 and 3.27% N as urea. Microbial protein production increased as the N level rose but with no change in the quantity of DM fermented in the rumen.

The high levels of the alpha-linked glucose polymers entering the duodenum in this experiment support the isotope dilution experiments of Ferreiro et al (1978) and Ravelo et al (1978) who found there was a positive linear relationship between glucose entry rate in the plasma and the level of rice polishings in the diet. This suggests an absorption of glucose from enzymic degradation of the glucose polymers in the duodenum. It has been previously reported that there is little or no effect upon rumen fermentation patterns due to the supplementation of rice polishings in the diet (Valdez et al 1977).

Apart from the obvious needs for glucose per se by the animal it could well be that the influx of such large quantities of glucose from the intestine of animals fed rice polishings affects the efficiency with which other essential nutrients such as amino acids are used. This effect is probably mediated by the action of the body hormones, predominantly insulin which is known to affect most aspects of protein synthesis, increasing both transport of metabolites into cells and reducing protein catabolism (see review by Manchester 1976). Of particular interest is the effect that certain amino acids and glucose have in simulating the effect of insulin in the initiation of protein formation in cells. All these intricate biochemical functions lead to increased rate and extent of body protein formation.

The tendency for total N entering the duodenum to increase with increasing levels of rice polishings in the diet has been mentioned before. This suggests that either microbial protein synthesis in the rumen is increased and/or there are substantial quantities of feed protein escaping degradation in the rumen. This aspect is treated more fully in the companion paper (Elliott et al 1978).

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References

- Allen S A and Miller E F 1972 Proc Nutr Soc 31:26A
- Binnerts W T, Van't Klooster AT & Frens A M 1968 Vet Rec 82:470
- Buttery P J and Arrison E F 1972 Biological efficiency of protein production (ed J W G Jones) Academic Press: London
- Elliot J M & Carpenter J R 1974 Site of starch digestion Proc 1974 Cornell Nutrition Conf for Feed Manufacturers Buffalo:NY USA
- Elliott R, Ferreiro H M & Priego A 1978 An estimate of the quantity of feed escaping degradation in the rumen of steers fed chopped sugar cane, molasses/urea supplemented with varying quantities of rice polishings Trop Anim Prod 3: 36-39
- Ferreiro A M, Priego A, Lopez J, Preston T R and Leng R A 1978 Glucose metabolism in cattle given sugar cane based diets supplemented with varying quantities of rice polishings Brit J Nutr (submitted)
- Hume I D, Moir R J and Summers M 1970 Synthesis of microbial protein in the rumen I influence of the level of nitrogen intake Austral J Agric Res 21:283-296
- Leng R A and Preston T R 1976 Sugar cane for cattle production: Present constraints, perspectives and research priorities Trop Anim Prod 1:1-22
- Lopez J and Preston T R 1977 Rice polishings as a supplement in sugar cane diets for fattening cattle: effect of varying levels of blood meal Trop Anim Prod 2:143-147
- MacRae J C and Armstrong D G 1968 Enzyme method for determination of linked glucose polymers in biological materials J Sci Food & Agric 19:578-581
- Manchester R L 1976 Hormonal control of protein metabolism. In Protein Metabolism & Nutrition (Ed Cole et al). Butterworths: London
- Minor S, MacLeod N A, Preston T R and Leng R A 1977 Studies on digestion in different sections of the intestinal tract of bulls fed sugar cane/urea with different supplements. Trop Anim Prod 2:163-174
- Preston T R & Bonsapetti E 1975 El uso de harina de carne y urea como suplementos en una racion de engorde de carne con cane de Azúcar integral picada Inform Anual 1974 CIEG Chetumal:Mexico
- Preston T R, Carcano C, Alvarez F J & Gutierrez D G 1976 Rice polishings as a supplement in a sugar cane diet: effect of level of rice polishings and of processing the sugar cane by derinding or chopping Trop Anim Prod 1:150-161
- Priego A, Wilson A & Sutherland T M 1977 The effect on parameters of rumen fermentation, rumen volume and fluid flow rate of zebu bulls fed chopped sugar cane supplemented with rice polishings or cassava root meal Trop Anim Prod 2:292-299
- Ravelo G, Fernandez A, Bobadilla M, MacLeod N A, Preston T R & Leng T R 1978 Glucose metabolism in cattle on sugar cane based diets: a comparison of supplements of rice polishings and cassava root meal Trop Anim Prod 3: 12-18
- Silvestre R, MacLeod N A & Preston T R 1977a Supplementation of sugar cane/ urea for growing cattle: effect of maize grain and different levels and sources of protein Trop Anim Prod 2:81-89
- Silvestre R, MacLeod N A & Preston T R 1977b Effect of meal, tries cassava root & groundnut oil in diets based on auger cane/urea or molasses/urea Trop Anim Prod 2:151-157
- Stevens A E & de Langen H 1960 New Zealand J Agric Res 3:312
- Valdez R E, Alvarez F J, Ferreiro H M Guerra F, Lopez J, Priego A, Blackburn T R, Leng R A & Preston T R 1977 Rumen n function in cattle given sugar cane Trop Anim

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