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Urea as a source of non-protein nitrogen for ruminants

II. Effect of urea as a non-protein source on digestibility and voluntary intake by sheep fed alkali treated rice straw

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Abstract : Rice straw, the largest annually harvested agricultural by-product in Sri Lanka, is essentially an energy feed high in cell wall material, but because of its low digestibility, the intake of digestible energy is often inadequate even to prevent live weight loss in mature ruminants. In recent years, chemical procedures have been elaborated for improving low quality forages and rice straw has been successfully upgraded in feeding value, to a medium quality hay, by spray treatment with NaOH solution. Low nitrogen content is a predominant factor limiting efficient utilization of roughage material but non-protein nitrogen supplementation has been successfully employed to overcome this problem. Inorder to assess the influence of non-protein nitrogen supplementation on its feeding value, rice straw, variety H_4, treated with 4% (w/w) NaOH solution (at the rate of 1.2 l/kg of straw) was fed *ad libitum* to growing sheep along with 100 g ground maize/animal/day, with or without urea. Urea represented 0 to 2.65% of the total dry matter consumed. Urea supplementation up to 1.87% resulted in a significant increase in digestibility. Beyond 1.87% there was no significant influence on digestibility, but voluntary intake increased. At 2.65% level of supplementation voluntary dry matter intake was 30% higher than the dry matter intake of diet containing no urea. It appears that 1.8 to 2.0% of the total dry matter consumed is the optimum level of urea supplementation for 4% NaOH (w/w) treated rice straw. Since insufficient sulphur could have influenced urea nitrogen utilization by rumen micro-organisms, ammonium sulphate may be a better source of npn for ruminants.

1. Introduction

Many low quality forages are essentially energy feeds high in cell wall material. Even so, they are little used as animal feeds because of their low energy yields. They are generally low in digestibility and intake and the intake of digestible energy is often inadequate to even prevent live weight loss in mature ruminants.

Alkali treatment can markedly increase the nutritive value of many poor quality roughages,[3,8,12,17,25,27] and sodium hydroxide treatment has been claimed to be the most effective.[14,22] Recent trials, in Sri Lanka, have indicated that rice straw, one of the largest annually harvested agricultural by-products, can be successfully up graded in feeding value, to a medium quality hay, by spray treatment with sodium hydroxide solution.[15,16]

A further factor limiting the efficient utilization of roughage material by ruminants is their low nitrogen content which is generally regarded as too low to sustain adequate activity of the cellulose and hemicellulose digesting microorganisms in the rumen. For efficient breakdown of lignocellulose in the rumen a nitrogen content of 1% in the DM of diets, the energy contents of which are less than 50% digestible is considered essential. In more digestible lignocellulose based diets nitrogen requirements may increase up to 1.5% to 2% of the DM.[23]

The usefulness of non-protein nitrogen (npn) compounds in the nutrition of the ruminants has been well established.[4,5,9,10,24]. However, despite the voluminous research carried out,[5] practical progress in this field has been relatively small, partly because of the complexity of nitrogen metabolism in the rumen, and partly because of the lack of data on applied research in the field.

The objective of the work reported here was to determine the effect of npn supplementation of NaOH treated rice straw on digestiblity and voluntary intake, using growing sheep and thereby quantify the optimum level of supplementation, for the preparation of practical rations. Urea was selected as the npn source as it is probably the commonest npn compound of choice as a protein replacer for ruminant feeding. The work was carried out at the Department of Animal Husbandry, Faculty of Agriculture, University of Peradeniya.

2. Experimental

Rice straw, variety H_4, chopped into 20 to 50 mm lengths was treated with 40 g NaOH dissolved in 1.2 litres of water per 1 kg of straw, according to the technique previously described.[16] Treated straw dried in an Unitherm oven at 98°C for 6 hours, was stored in bags until required for the feeding trial.

The experiment was designed as a complete randomized block experiment with seven treatments. All animals were offered *ad libitum* treated straw + 100 g ground maize with or without urea. The quantity of urea in the concentrate (0, 5, 8, 10, 12, 15 or 18 g urea/100 g concentrate, representing 0 to 2.65% of total DM consumed) represented the seven treatments (Table 2). Concentrate and treated straw was offered sepeiately, twice daily, in equal amounts. Water and a standard mineral mixture were available *ad libitum* through out the feeding trial.

Growing Jaffna × Bikaneri female sheep of average live weight 21.7 kg (range 20.5 to 25.5 kg) were used to measure the apparent digestibility of the treated straw rations. Three animals were used for each treatment. All animals were housed in individual digestion cages designed to enable the separate collection of faeces and urine.

The feeding period was of 20 days duration, the first 12 days to allowing for adjustment to the ration with voluntary intake and digestibility measured over the last 8 days. Voluntary intake was measured by feeding daily, an amount of ration to insure an excess of at least 10% over previous days intake and determining actual intake by daily weighing of refused feed.

Daily faecal collection for each sheep during the collection period was weighed, sampled and frozen for later analysis. Urine was collected daily in plastic buckets containing 25 ml of 1N HCl ; the volume determined, a 2% aliquot was refrigerated for later analysis.

Proximate constituents,[2] acid detergent fibre (ADF), cellulose and silica[13] were determined for treated straw and the concentrate.

The digestibility of straw organic matter was calculated by assuming the organic matter digestibility of concentrate to be 85%.

3. Results

The average chemical composition of treated straw and ground maize used in the feeding trial is shown in Table 1. The composition, energy value and crude protein content of the experimental diets are shown in Table 2. The consumption of treated straw and increasing levels of urea had no ill effects on the health of animals.

Addition of urea up to 1.87% of the total DM consumed, (0 to 10 g urea/100 g concentrate) significantly ($P < 0.01$) increased both dry and organic matter digestibility of NaOH treated straw diets. Beyond this level however, there was no further increase in digestibility (Table 3).

Dry matter intake remained constant up to 1.87% level of urea supplementation. Above this however, an increase in the level of supplementation increased the DM intake markedly. At 2.65% level of supplementation, voluntary DM intake was 30% higher than the diet containing no urea. This also resulted in an increase in digestible energy intake (Table 3).

All urea fed animals showed a positive nitrogen balance compared to the control treatment without any urea. Urea had no influence on voluntary intake of water and output of urine.

TABLE 1. The average chemical composition of concentrate and treated straw used in the feeding trial

Component	Treated straw	Concentrate
	g/100 g dry matter*	
Ash	16.5	1.3
Crude protein	4.2	8.4
Crude fibre	30.8	2.2
Acid detergent fibre (ADF)	56.3	5.1
Cellulose	38.9	4.2
Silica	9.9	—

*dry matter content — straw — 96.6
dry matter content — concentrate — 93.4

TABLE 2. Composition and energy value of rations used in the feeding trial.

Ration number	1	2	3	4	5	6	7
Amount of NaOH (g/kg straw)	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Volume of water (l/kg straw)	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Amount of concentrate fed with straw (g/animal/day)	100	100	100	100	100	100	100
Quantity of urea added to concentrate (g/100g concentrate)	0	5.0	8.0	10.0	12.0	15.0	18.0
Crude protein content of ration (g/100 g DM consumed)	5.04	7.76	8.16	10.42	10.78	10.81	12.56
Intake of urea (%) (intake as a % of total DM consumed)	0	0.94	1.33	1.87	2.02	2.18	2.65
Estimated ME content of ration (MJ/kg DM)	6.18	7.56	7.46	8.60	8.43	8.22	8.48

TABLE 3. Intake and apparent digestibility of dietary constituents

Ration number	1	2	3	4	5	6	7	S.E. of difference between means
Intake								
Urea (%) (intake as a % of total DM consumed)	0	0.94	1.33	1.87	2.02	2.18	2.65	—
Digestible energy (MJ/day)	4.16	4.96	5.52	5.67	6.18	6.99	7.10	—
Straw-ad libitum (g/DM/kg W 0.75/day)	44.8	43.6	41.3	43.9	49.98	54.0	58.1	± 2.72
Water (Voluntary intake 1/day)	1.386	1.563	1.823	1.832	1.492	1.897	2.261	± 0.316
Digestibility of dietary constituents (%)								
Dry matter (DMD)	41.1	51.1	51.2	58.4	57.3	57.2	59.0	± 2.56
Organic matter (OMD)	46.7	56.9	56.5	64.9	63.8	62.4	64.3	± 1.98
Digestible organic matter in dry matter (DOMD)	40.2	49.1	48.5	55.9	54.8	53.4	55.1	± 2.48
Derived digestibility of straw organic matter	37.4	49.9	50.2	59.9	59.1	58.1	60.5	± 3.53
Output								
Urine (1/day)	0.911	0.762	0.926	1.033	0.739	1.219	1.434	± 0.133
N balance (g/day)	−3.71	+ 1.56	+ 2.18	+ 3.90	+ 4.40	+ 6.60	+ 5.35	—

4. Discussion

Addition of urea (0 to 2.65% of total DM consumed) increased the crude protein equivalent of the straw diets from 5.0 to 12.5%, but this increase was not proportionate to the increase in the urea content of the ration. This was due to the comparatively higher intake of straw DM at the upper levels of urea supplementation.

The results of the present experiment are in general agreement with work reported elsewhere on both treated and untreated cereal straw rations supplemented with urea. With untreated straw, there had been many instances where the addition of urea resulted in increases in digestibility and voluntary intake of poor quality roughages.[1,11,19] There were other instances, however, where urea supplementation had no influence on the utilization of low quality roughages.[6,18,20,21] Similar results have been obtained with alkali treated roughages as well. Bramen and Abe[7] found no improvement in digestibility of NaOH treated (4% NaOH, w/w) wheat straw when it was supplemented with 1.0 or 2.0% urea. Donefer *et al*[12] observed no significant effect on digestibility, but voluntary intake increased three fold when 2.5% urea was added to oat straw treated with 8% (w/w) NaOH solution. They explained this observation on the basis that nitrogen was a limiting factor and that adequate supply of nitrogen by way of urea resulted in an increase in the rate of microbial digestion and thus voluntary consumption of forage by the animal. The work of Rexen *et al*[26] also supports the view that urea supplementation need not necessarily increase the utilization of treated straw diets.

As pointed out by Balch,[4] in spite of more than half a century of experimentation with npn compounds, there is still much doubt about the response to npn supplementation of diets of cattle and sheep. As he rightly pointed out, extra nitrogen in the form of urea or any other npn compound, cannot be expected to give responses, if energy becomes a limiting factor.

The results of the present experiment shows that even with alkali treated straws, energy can become a limiting factor for urea utilization. Alkali treatment increases the digestible energy content of the treated material and thereby its ME content. This will encourage the utilization of npn by rumen micro-organisms. But beyond a certain level any further addition of npn will not give higher responses as energy becomes a limiting factor. It is thus evident that with 4% NaOH treated rice straw, the optimum utilization of urea occurs at 1.87% level of supplementation at which stage the metabolizable energy availability of treated material is 8.60 MJ/kg DM.

The higher intake achieved beyond 1.87% level of urea supplementation could have been due to an increased rate of passage of digesta through the digestive tract. The increase in intake was not associated with an increase in digestibility but it influenced the digestible energy intake.

Sulphur could have been a limiting mineral element in npn utilization by rumen micro-organisms as no additional sulphur was given with the diet in the reported work. In this respect ammonium sulphate could be a better source of npn for ruminants but its role as a npn source has to be first ascertained before it could be used in practical rations. Thus, more research is required before any conclusions could be drawn on the optimum level of npn supplementation for alkali treated rice straw.

Cost analyses have been done on data from many feeding trials conducted in various countries to establish the economic feasibility of feeding alkali treated straw to farm animals. While in Europe the substitution of treated straw for hay and silage appears to be profitable, it does not seem to be so in North America even when the straw is produced in the same farm. However in countries where straw is traditionally fed to livestock, alkali treatment is clearly profitable, especially when straw has no value other than the cost of collecting it and treating it on the farm. In Sri Lanka, the main cost would be that of the cost of alkali, if family labour of the small farm unit is not taken into account. The economic feasibility of treated straw as a substitute for fodder in Sri Lanka is however yet to be established under field conditions.

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