EFFECT OF SUPPLEMENTATION WITH PROTEIN MEAL ON THE GROWTH OF CATTLE GIVEN A BASAL DIET OF UNTREATED OR AMMONIATED RICE STRAW

H.B. Perdok[1] and R.A. Leng[2]

Department of Biochemistry, Microbiology and Nutrition,
University of New England, N.S.W., 2351, Australia

Summary

A 98 d feeding trial carried out to study liveweight change and rumen metabolites in heifers weighing initially 275 kg and given either untreated or ammoniated rice straw supplemented with 0, 0.4, 0.8 or 1.2 kg protein meal consisting of cottonseed meal (60). All 32 animals received 0.6 kg rice polishings/hd/d and had continuous access to molasses/urea block-licks containing 15% urea.

The effects on growth rates of treatment of the straw with ammonia and of supplementation with bypass protein were additive. The heifers fed ammoniated straw grew 267 g/hd/d ($p < 0.001$) faster and consumed 11% ($p < 0.05$) more straw than the heifers on untreated straw. The mean growth response to bypass protein was 0.37 kg gain/kg protein meal supplied. Supplementation with protein meal tended ($p = 0.06$) to depress intake of straw, but straw intakes of the unsupplemented groups were high.

Small changes in the composition of the block-licks that were fed throughout the feeding trial led to changes in block intake and in intake of untreated straw.

Increasing quantities of protein meal fed were associated with linear increases in concentrations of ammonia ($p < 0.05$) and in molar percentages of iso-butyrate ($p < 0.01$), iso-valerate ($p < 0.01$) and valerate ($p < 0.01$) in the rumen fluid of the heifers on a basal diet of untreated straw. However, in the rumen fluid of the heifers given ammoniated straw, the levels of these metabolities were not affected by the quantity of protein meal given.

(Key Words: Cattle, Rice Straw, Treatment with Ammonia, Supplementation, Bypass Protein, Efficiency of Feed Utilisation, Growth Rate)

Introduction

Cattle fed solely on rice straw generally have a voluntary dry matter intake of about 2 kg/100 kg live weight and barely maintain weight (see review by Doyle et al., 1986). The underlying cause of the low voluntary intake and low animal performance are a low actual digestibility of the straw which is caused by the high lignification and deficiency of critical nutrients to support an efficient population of micro-organisms in the rumen. Diets consisting solely of straw are associated with a low availability and an imbalance of nutrients (Leng, 1985) and the metabolisable energy is inefficiently used in body weight gain (Leng, 1989).

The most obvious way of increasing voluntary intake of straw is to treat the straw with ammonia to improve its digestibility (Sundstøl and Owen, 1984) and supplementation to provide deficient nutrients and to balance the nutrients absorbed with requirements (Leng, 1982; Nolan et al., 1986).

Protein supplements which escape fermentation in the rumen (bypass protein) have been very effective in enhancing growth rates of young cattle consuming low digestibility fibrous feeds (see for review Leng et al., 1987).

According to the Agricultural Research Council (ARC, 1980), cattle weighing over 200 kg and gaining less than 0.75 kg per day can obtain their amino acid requirement from digested rumen microbes and require only supplementation with fermentable nitrogen (or rumen degradable N) when on diets of low metabolisable energy density.

[1]CAF, De Bolder 75, 9206 AK, Drachten, The Netherlands.

[2]Address reprint requests to Prof. R.A. Leng, Dept. of Biochemistry, Microbiology and Nutrition, University of New England, N.S.W., 2351, Australia.

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In the study now reported, cattle were given either untreated or ammoniated rice straw (*Oryza sativa*) and the effect of four levels of protein meal on liveweight change was investigated. All animals were supplemented with 0.6 kg rice polishings, mainly to supply some dietary fat. To ensure adequate availability of rumen ammonia, molasses/urea blocks containing 15% urea were available to the animal at all times.

Materials and Methods

Animals, experimental design and diets

Thirty-two Friesian heifers of approximately 18 months of age and weighing on average 275 ± 21 kg were allocated by stratified randomisation to 8 semi-covered group pens. Animals in the 8 pens were given free access to either untreated (4 groups) or stack-ammoniated (4 groups) rice straw (cv. Inga) and within each basal diet, groups were provided with 0, 0.4, 0.8 or 1.2 kg protein meal pellets/hd/d according to a 2 x 4 factorial design. All animals received 0.6 kg rice polishings/hd/d and had continuous access to molasses/urea blocks containing 15% urea. The cattle were given straw plus supplements between 09:00 and 11:00 h. The protein meal and rice polishings were given to individual animals that were tied for 30-60 min until they had consumed their supplement. Straw was placed in a hay rack and was given 15 to 20% in excess of the previous day's intake. The experiment lasted 126 days, but the first 28 days were used as an adjustment period.

Ammoniation of straw

Batches of about 1,500 kg straw were stacked under black plastic sheets and the stacks were injected with 30 g anhydrous ammonia per kg straw. Each stack was opened after 9 weeks and the treated straw was placed in the hay racks without prior aeration. The plastic sheets were sealed at all times to reduce ammonia loss.

Composition of molasses/urea blocks

The molasses/urea blocks contained 41% sugar cane molasses, 15% urea, 12% calcium hydroxide, 10% calcium hydrogen orthophosphate, 2% magnesium oxide, 2.5% sodium sulphate, 1% potassium chloride, 4% Pfizer 422 mineral and vitamin mix, 10% rice polishings and 2.5% lucerne chaff. Blocks (5 kg each) of that composition were used from days 1-38, 52-74 and 88-98. From days 39-51, the expensive food-grade calcium hydrogen orthophosphate was replaced by dicalcium phosphate. From days 75-87, $CaHPO_4 \cdot 2H_2O$ was not available and was replaced by Na_2HPO_4 (dibasic sodium phosphate).

Composition of protein meal pellets

The protein meal pellets consisted of 60% solvent-extracted cottonseed meal, 30% soybean meal and 10% meat meal. This mixture contained 42% CP (table 1) and relative to formaldehyde treated casein, about 60% of the protein appeared to bypass rumen fermentation as indicated by a wool growth assay (Leng et al., 1984).

Liveweight change and feed intake

The heifers were weighed every fortnight, before feeding of supplements and adding straw to the racks. Feed intake was monitored over the whole period but measured accurately over three

TABLE 1. MEAN CONTENTS OF DRY MATTER (DM IN MG/G), NITROGEN (N) AND ASH (MG/G DM) AND DM LOSS (MG/G DM) FROM SAMPLES INCUBATED FOR 24 H IN DACRON BAGS IN THE RUMEN OF STEERS OF FEEDS USED

Feed	No. of duplicated samples	DM	N	Ash	24 h DM loss from dacron
Untreated rice straw	9	905	6.0[a]	149[b]	349[a]
Stack-ammoniated	9	883	18.6[b]	143[b]	460[b]
Protein nuts	1	908	67.3[c]	87[a]	678[c]
Rice polishings	1	914	21.1[b]	92[a]	772[d]

[a-d]Means in the same column with a different superscript differ statistically ($p < 0.01$).

periods of 5 days each (days 19-23, 48-52 and 75-79).

Protein meal pellets and rice polishings were always totally consumed.

An estimate of the intake of molasses/urea blocks was obtained by recording the time between replacement of blocks, which weighed 5 kg each. Each day during a measurement period, all straw was removed from the hay rack and feeding troughs underneath; this was weighed and a sample of about 150 g was taken for DM determination.

Dry matter content was estimated by drying duplicate samples to constant weight (48 h) in a forced-draught oven at 80°C. The total and straw DMI were expressed in kg per 100 kg live weight, based on the mean weight of the group measured in the week before and after the DMI measurement period.

Feed analysis

Nitrogen in the feed samples was determined by Kjeldahl methods (AOAC, 1980). The rumen degradability of the feeds was estimated by a modification of the "nylon bag technique" described by Orskov et al. (1980) and involved incubation of duplicate samples (each 3 g DM) in polyester bags (pore size 44 μm; 33% of the cloth surface open) for 24 h in the rumen of each of three mature steers. The ash content was determined by AOAC (1980) procedures.

Ruminal ammonia and volatile fatty acids

Samples of rumen liquor were obtained from all animals by a rubber tube inserted into the mouth and then into the rumen before feeding on d 27, 57 and 85 and after feeding on d 28, 58 and 86. The samples were frozen after acidification until analysed.

Ammonia concentrations were determined by an auto-analyser method (Crooke and Simpson, 1971; modified by Bietz, 1974).

Total volatile fatty acid (VFA) concentrations and molar proportions of individual VFA were determined by gas liquid chromatography (Erwin et al., 1961), using isocaproic acid as an internal standard (Geissler et al., 1976).

Statistical analyses

Feed composition data were subjected to analysis of variance and the SNK-test (Steel and Torrie, 1980) was used as a multiple comparison procedure between the means.

Effects of the type of straw and level of protein meal on live weight change, feed intake, ruminal ammonia concentration, total VFA concentration and VFA proportions were analysed by a split plot analysis for a repeated measures experiment, testing orthogonal linear, and where appropriate and possible, quadratic and cubic contrasts between periods. The Greenhouse-Geisser correction factor (Winer, 1971) was used to adjust the degrees of freedom in the sub-plot section. The consistency of live-weight gain per inter-weighing period was further tested by repeated measures analysis of cumulative gain. The linear and quadratic components of the effects of level of protein meal and straw by protein meal interaction were examined for all variables measured and reported where significant.

Results

Feed analysis

The analysis of the feedstuffs used is given in table 2. The molasses/urea blocks had a calculated nitrogen content of about 72 mg N/kg DM.

TABLE 2. STRAW DMI AND TOTAL DMI (KG/100 KG LIVE WEIGHT) OF CATTLE FED A BASAL DIET OF AMMONIATED (AS) OR UNTREATED (US) RICE STRAW WITH 0, 0.4, 0.8 OR 1.2 KG PROTEIN MEAL/HD/D. THE PROPORTION OF STRAW IN THE DIETS IS ALSO GIVEN

	Straw DMI					Total DMI				
	0.0	0.4	0.8	1.2	Mean	0.0	0.4	0.8	1.2	Mean
AS	2.71	2.66	2.62	2.48	2.62	2.99	3.05	3.12	3.06	3.05
AS (Proportion of DMI)						0.91	0.87	0.84	0.81	0.86
US	2.55	2.37	2.20	2.30	2.35	2.89	2.80	2.68	2.88	2.81
US (Proportion of DMI)						0.88	0.85	0.82	0.80	0.84

Animal health

Throughout the experiment, all animals appeared to be in good health.

Liveweight change

The mean liveweight gain of heifers given ammoniated straw was 491 g/hd/d, more than twice ($p < 0.001$) that of 224 g/hd/d recorded for the animals given untreated straw. The slopes of the linear growth lines (i.e. cumulative gain) also differed significantly ($p < 0.001$).

The mean live weight change varied from -8 g/hd/d on the untreated straw diet without a protein supplement to 648 g on the ammoniated straw diet supplemented with 1.2 kg protein meal (figure 1). The relationship between the daily gain Y (g/hd/d) and the intake of protein meal X (kg/hd/d) was of the form:

$Y = -10 + 882X - 572X^2$ ($R^2 = 0.999$) for cattle given untreated straw and

$Y = 283 + 494X - 158X^2$ ($R^2 = 0.099$) for cattle given ammoniated straw.

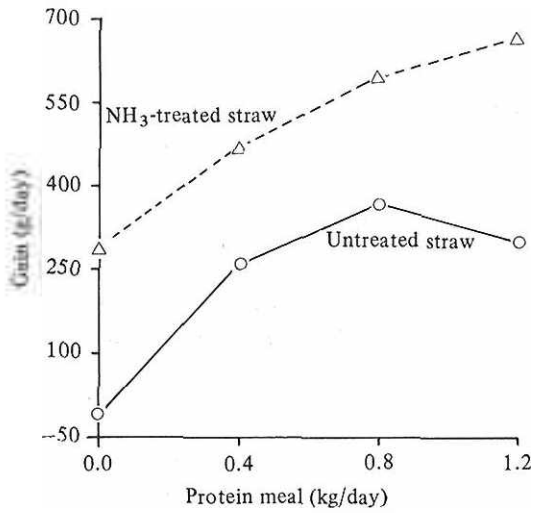

Figure 1. Growth response to different levels of protein meal supplementation of cattle given ammoniated (NH_3-treated straw) or untreated rice straw (untreated straw).

Straw dry matter intake and total dry matter intake

The animals given ammoniated rice straw (AS) consumed 11% ($p < 0.05$) more straw than the animals on untreated straw (US) (2.62 and 2.35 kg straw DM/100 kg live weight respectively). The mean total DMI of the AS groups was 3.05 kg/100 kg live weight measured in the US groups.

Untreated straw DMI and total DMI of the heifers on a basal diet of untreated straw decreased over the three periods in which DMI was measured. The DMI of ammoniated straw was consistent over the three periods (see also table 3). This caused a significant ($p < 0.01$) period effect and a significant ($p < 0.05$) straw by period interaction for both straw DMI and total DMI. There were also large ($p < 0.001$) differences in voluntary intake between the five consecutive days in each period that feed intakes were measured, but no general pattern emerged.

For both straw types, the straw DMI decreased

TABLE 3. ASSOCIATION BETWEEN PHOSPHORUS SOURCE IN BLOCK, BLOCK INTAKE (KG), VOLUNTARY STRAW INTAKE (KG STRAW DM/100 KG LIVE WEIGHT) AND RUMEN AMMONIA CONCENTRATION (MG NH_3-N/L) IN CATTLE FED UNTREATED (US) OR AMMONIATED (AS) RICE STRAW. THE DAYS WHEN THE MEASUREMENTS WERE MADE ARE ALSO GIVEN

Phosphorous source	Block intake		Straw DMI			NH_3-N		
	days	kg/hd/d	days	US (kg/100kg LWt)	AS (kg/100kg LWt)	days	US (mg/l)	AS (mg/l)
$CaHPO_4 \cdot 2H_2O$	1-38	1.1^c	19-23	2.56^c	2.69^a	27-28	93^c	211^c
Dical·phosph.	39-51	0.3^b	48-52	2.35^b	2.52^a	57-58	88^b	182^b
Na_2HPO_4	75-87	0.1^a	75-79	2.15^a	2.64^a	85-86	64^a	138^a
Mean	1-98	0.4	–	2.35	2.62	–	81	177

^{a,b,c}Values in the same column with a different superscript differ ($p < 0.05$)

($p=0.06$) as the intake of protein supplement increased (table 2). There were no significant differences in total DMI between the groups receiving different quantities of protein meal, neither within the groups of cattle given ammoniated straw, nor in those fed untreated straw. Both these observations indicate that the protein meal partly substituted for straw.

Intake of molasses/urea blocks

There was little difference in intake of molasses/urea blocks between the 8 groups of 4 heifers. The mean intake was 0.4 kg block/heifer/day. However, what were minor changes in block composition, viz. in phosphorous source, caused dramatic drops in block intake and apparently in intake of untreated straw (table 3). As would be expected, lower block (i.e. urea) intakes are reflected in lower rumen ammonia concentrations. Sampling of rumen fluid took place 5-7 d after the DMI periods and this may have led to an overestimation of ammonia levels in rumen fluid in the second DMI period. During that period, unpalatable Na_2PO_4 was replaced by palatable $CaHPO_4 \cdot 2H_2O$ after DMI measurement, but before sampling of rumen liquor.

Ruminal ammonia concentration and VFA proportions

In comparison with cattle fed untreated straw, cattle fed ammoniated straw had higher rumen ammonia concentrations, higher molar proportions of acetate and butyrate, but lower molar proportions of propionate, iso-valerate and valerate (table 4).

Linear regressions of the level of rumen fluid metabolites against level of protein meal for cattle fed ammoniated straw was non significant but for cattle fed untreated straw concentrations of ammonia and molar proportions of iso-butyrate, iso-valerate and valerate were related to protein meal intake (figure 2).

Discussion

Animal health

The rice straw (cv. Inga) used in this trial was of the same batch as that which repeatedly caused hyperexcitability in cattle consuming the straw after it had been ammoniated in an oven (Perdok and Leng, 1987). The present experiment was conducted in winter and temperatures of the straw in the stacks never exceeded 60°C which was below the critical temperature of 70°C apparently needed to generate toxins in straw on ammoniation

Liveweight change, straw DMI and total DMI

Response curves such as given in figure 1 are ideally suited for comparing live weight gain of cattle fed ammoniated or untreated straw with different quantities of supplements. Such response curves can also be used for biological or economic evaluations. The data depicted in figure 1 show that when ammoniated straw replaces untreated straw, either a smaller quantity of supplement is required for the same daily gain (horizontal comparison) or more live weight gain is realised for the same quantity of supplement (vertical comparison).

The mean weight gain of cattle given a diet based on ammoniated straw in the present study was 119% higher than that of similar animals on untreated straw (491 vs 224 g/hd/d). The higher rate of live weight gain on ammoniated straw is apparently attributable to a higher straw digesti-

TABLE 4. DIFFERENCES BETWEEN AMMONIA CONCENTRATIONS (MG NH_3-N/L), TOTAL VFA CONCENTRATION (MMOLES/L) AND MOLAR PERCENTAGES OF INDIVIDUAL VFA IN THE RUMEN FLUID OF CATTLE FED AMMONIATED OR UNTREATED RICE STRAW

	NH_3-N	Total VFA concentration	% Total VFA as					
			Acet.	Prop.	But.	I-But.	I-Val.	Val.
Ammoniated straw	177	77	75.1	14.8	8.9	0.40	0.41	0.42
Untreated straw	81	71	74.5	15.9	8.2	0.44	0.49	0.47
Difference	96	6	0.7	−1.1	0.7	−0.03	−0.07	−0.05
Sign. of difference	***	*	**	***	***	n.s.	*	***

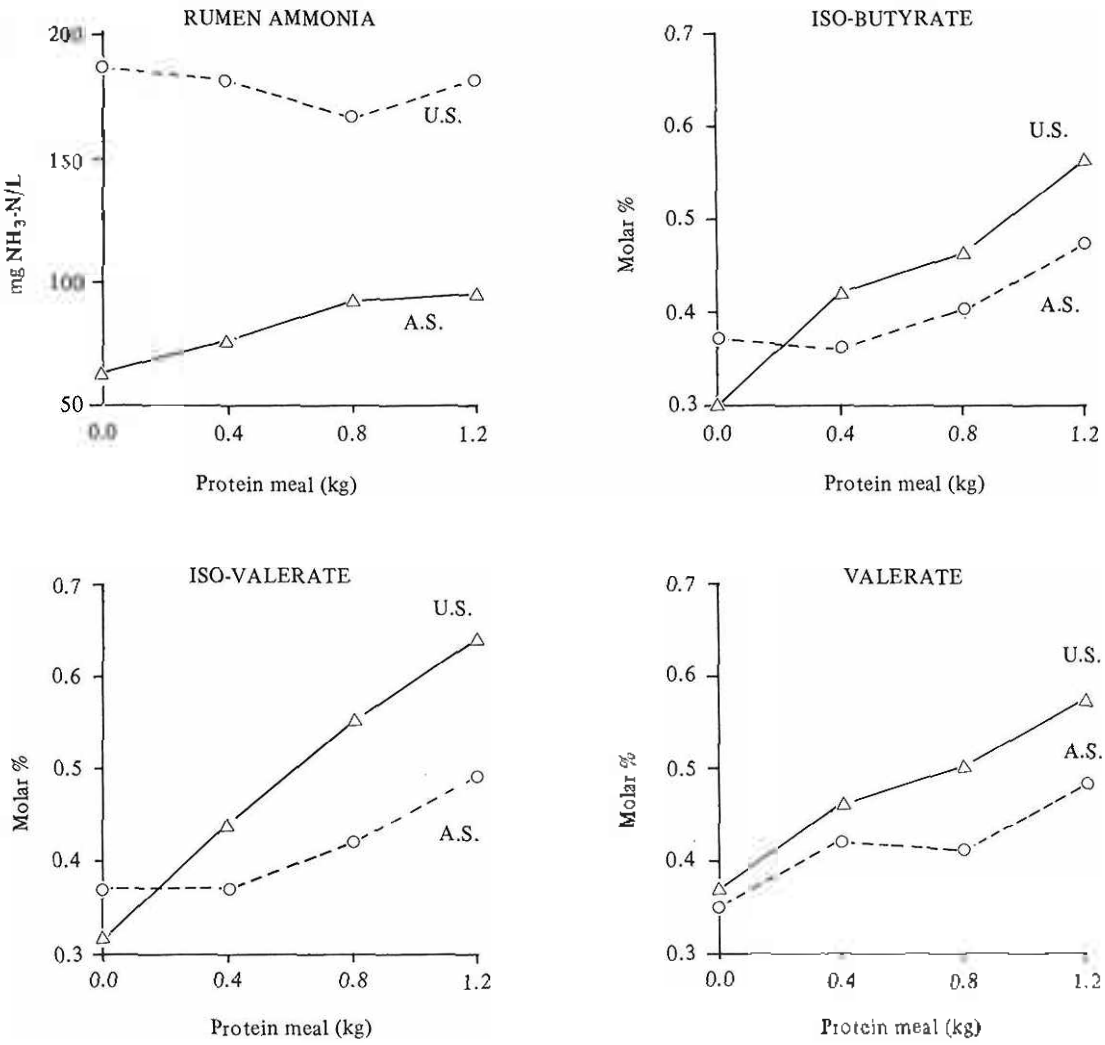

Figure 2. Graphs showing interaction between type of straw (US = untreated straw; AS = ammoniated straw) and level of protein meal on rumen fluid concentration of ammonia and molar percentages of iso-butyrate, iso-valerate and valerate. Each point is the mean of 24 observations (4 heifers sampled 3 times before and 3 times after feeding).

bility (in sacco DMD of 460 mg/g DM for ammoniated straw vs 349 for untreated straw = +32%, table 2), a higher straw DMI (2.62 vs 2.35 kg/100 kg live weight = +11%) and a higher total DMI (3.05 vs 2.81 kg/100 kg live weight = +9%).

The effects on growth of increasing digestibility of straw by treatment with ammonia gas agree with results reported in the literature. Mira *et al.* (1983), using 380 kg cattle given ammoniated barley straw plus rolled barley (2:1) or barley straw (plus urea) and rolled barley found large improvements in gain (929 vs 502 g/hd/d = +85%) and in straw DMI (5.33 vs 4.28 kg = +12%) in the cattle given ammoniated barley straw. Ørskov *et al.* (1983) fed Friesian heifers (440 kg) iso-nitrogenous diets consisting of ammonia-treated or urea-supplemented barley straw and obtained large increases in liveweight change (+324 vs −447 g/hd/d), in in vivo DMD (59 vs 50%) and in DMI (5.9 vs 3.9 kg/hd/d).

The present trial suggests that with cattle

weighing over 200 kg and fed a diet that consisted of 0.80-0.90 of untreated or ammoniated rice straw, considerable improvements in daily gain and feed conversion efficiency can be obtained from small supplements (0.4-1.2 kg/hd/d) of a bypass protein meal. Large responses in liveweight gain to small supplements of bypass protein were also reported by Smith et al. (1980), Holzer et al. (1986) and Lee et al. (1987), and addition to the diet of bypass protein enhanced the growth rate of cattle already supplemented with urea in work by Lindsay et al. (1982), Mullins et al. (1984) and Perdok and Leng (1986). The cattle in all studies cited above weighed between 200 and 400 kg and were fed on a basal diet of low quality roughages. The responses observed therefore raise questions about the validity of the ARC (1980) recommendations that cattle over 200 kg consuming a diet with a low energy density and growing less than 0.75 kg only need to be supplemented with rumen degradable nitrogen.

In view of the small quantities of protein meal given to the cattle in the present trial, the partial substitution of protein meal for rice straw was unexpected. Substitution, despite the low levels of protein meal may have been influenced by inclusion in the basal diet of 0.6 kg rice pllishings and 0.4 kg molasses/urea block. The basal diet alone, therefore, more closely matched the nutrient requirements of the animals than did straw alone and voluntary intake, without protein meal, was consequently high (see table 2). Lindsay and Loxton (1981) and Lindsay et al. (1982) carrying out research in the tropics observed that steers and mature cows increased their intake of roughage (with 2% urea) by 32 and 31% when given 0.5 and 1 kg protected protein meal respectively. However, their basal diets consisted of speargrass (*Heteropogon contortus*) hay without other additives and the stimulation in intake of hay when the protein meals were based only reached the levels that would have been normally expected. In other words prior to supplementation the intake of hay was markedly depressed. This has led Leng (1989) to suggest that an inefficient utilization of feed by cattle in the tropics results in a metabolic heat load which depresses intake. This is eliminated when the diet is better balanced with a bypass protecin meal.

Creek et al. (1984), working with cattle of about 300 kg in Egypt, found substitution of "concentrate" (16% CP) for rice straw, with a tendency for ammoniated rice straw to be replaced to a larger extent than untreated rice straw.

Molasses/urea block-licks

In this trial there were no differences in intake of molasses/urea blocks between cattle fed on untreated and ammoniated straw, indicating that the cattle offered the untreated straw did not compensate their low N-intake by consuming more of the 15% urea block-licks. Conversely an intake of 400 g of block per day was sufficient to meet fermentable N requirements of animals on untreated straw but did not cause ammonia toxicity in animals on the treated straw.

In a 45-day feeding trial, Kunju (1986) observed that lactating Surti buffaloes, that had been accustomed to molasses/urea blocks for over 1 year, apparently balanced their N intake when block-licks were offered free choice. The buffaloes consumed 0.59 kg of a 15% urea block per head per day when only rice straw was on offer, but only 0.17 kg block/hd/d when the straw was supplemented with 3.4 kg of a 20% CP concentrate mixture. It is possible that changes in block composition and consequently in block intake (table 3) partly explain why the cattle in the present study failed to adjust. It is also possible that 'nutritional wisdom' takes a long time to become established.

Intake of untreated straw apparently depended on intake of block-licks (i.e. urea; see table 3). This could be of great practical importance and confirmed the dependence of voluntary intake of rice straw on level of urea in the diet (Perdok and Leng, 1989; see also Campling et al. 1962). Kunju (1986) reported a similar stimulative effect of molasses/urea blocks on intake of untreated rice straw by cattle and buffalo in India.

In the present trial, voluntary intake of ammoniated straw was apparently not stimulated by provision of molasses/urea blocks, indicating that there was adequate fermentable N in the ammoniated straw. In another trial (Perdok and Leng, 1986) it was found that supplementation with urea (1.2% of straw DM) at the time of feeding actually depressed intake of ammoniated wheat straw ($p < 0.01$).

Ruminal fluid ammonia concentration and VFA proportions

The mean ruminal ammonia concentration of the animals given untreated straw (US) was lower than that of the animals on ammoniated straw (AS) (81 vs 177 mg NH_3-N/l). The obvious reason for this is the large difference in straw N content (table 1), because both groups had similar intakes of 0.4 kg molasses/urea block (i.e. about 60 g urea/hd/d). Even if only 56% of the N added to rice straw by ammoniation is available (Dulphy et al., 1984), then for the observed DM intake of 8.5 kg straw, 130 g urea would be required to match the N supplied by ammoniated straw.

The results of this trial also suggested that ruminal fluid ammonia concentration is a reasonable index of block (i.e. urea) intake (table 3). Comparison of the data on ruminal fluid ammonia between animals within groups suggested a large variation in block intake. Spraying of a solution of urea on the straw may be a more reliable way of ensuring an adequate intake of urea by cattle than can be attained with urea/molasses block licks, but the latter is often a much more practical way of supplementing animals particularly in developing countries (Preston and Leng, 1984).

The ratio between the energy supplied by propionate and total VFA energy (termed the glucogenic energy/VFA energy ratios or G/E ratio) constitutes a useful index of the balance of the major VFA as nutrients for the host animal (Preston and Leng, 1987). Blaxter (1967) gave the heats of combustion of acetate, propionate and butyrate and appropriate weight to those is given by calculating the ratio of the energy in propionate to total VFA energy ratio (G/E ratio) as:

$$\text{G/E ratio} = \frac{\text{propionate}}{\text{propionate} + 0.6\ \text{acetate} + 1.4\ \text{butyrate}}$$

where the VFA are expressed as molar percentages. The G/E ratio in the ruminal fluid of ruminants fed fibrous residues is typically in the range 0.20-0.30 and reflects a fermentation pattern of 70-75 acetate, 15-20 propionate and 5-10 butyrate. The G/E ratio in the rumen liquor grain-fed cattle is typically in the range 0.40-0.50.

In the trial presented here, the G/E ratios were similar for all groups and had a mean value of 0.20 for the cattle given ammoniated straw and 0.22 for the cattle on untreated straw. The possible deficiency of glucose precursors (i.e. propionate) may have been partly compensated for by the escape of rice polishings from the rumen, thus supplying protein and alpha-linked glucose polymers for digestion and absorption in the intestines. Work by Leng and Preston (1976) and Elliot et al. (1978a, b) suggested that a considerable proportion of the protein and glucose provided by rice polishings escaped degradation in the rumen of cattle given a basal diet of sugar cane.

If ruminal ammonia concentration and VFA proportions of iso-butyrate, iso-valerate and possibly valerate can be used as indices of protein breakdown, then it is of interest that these variables in the rumen fluid of heifers given ammoniated straw were not influenced by the quantity of protein meal consumed (figure 2). This either implies that true protein is broken down to a minor extent, in the rumen of cattle on ammoniated straw or that the higher fermentability of ammoniated straw increases the uptake of these products by the rumen micro-organisms. As the proteins in the pellets were apparently degraded to an extent of 40% in the rumen of sheep, as estimated by a wool growth assay (Leng et al. 1984), the latter explanation is the more likely one and indicates that perhaps microbial growth efficiency is higher in the rumen of cattle given ammoniated straw compared with untreated straw plus urea. The lower mean proportions of branched-chain and higher VFA measured in the rumen liquor of the heifers on ammoniated straw compared with those on untreated straw may also be explained if lysis of microbial cells and degradation of the cells is lower on ammoniated straw.

Considerable evidence exists that ammonia, iso-butyrate, isovalerate and possibly n-valerate are essential nutrients for the growth of cellulolytic micro-organisms in the rumen (Bentley et al., 1954; Bryant and Doetsch, 1955; Allison et al., 1958; Hemsley and Moir, 1963; Dehority et al., 1967; Van Gylswyk, 1970; Bryant, 1973; Felix et al., 1980; Papas et al., 1984; Mir et al., 1986). The requirements for these nutrients by cellulolytic micro-organisms which are "fed" ammoniated straw can be expected to be high because of the combination of a high cell wall content, a high cell wall digestibility and a low retention time in the rumen. Saadullah (1986) reported an additional liveweight gain of 62 g

for a supplement of 15 g fishmeal in calves given urea-ensiled rice straw, but was unable to explain this enormous response. In sheep given ammoniated wheat straw, Romulo (1986) measured an increase in live weight gain of 40 g (from 19 to 59 g/hd/d) and in clean wool growth of .96 g (from 2.79 to 3.75 g/hd/d) in response to a supplement of 150 g lucerne chaff. Both fishmeal and lucerne hay may release considerable quantities of iso-butyrate and iso-valerate into the rumen fluid (Smith et al., 1980; Romulo, 1986; Ndlovu and Buchanan-Smith, 1985) and it is tempting to suggest a cause and effect relationship. However, recently Maeng et al (1989) reported studies which indicated that amino acids were not necessarily required cellulolytic by rumen micro-organisms, the microbial growth yield of rumen micro-organisms growing on cellulose was the same on a urea source as on a urea plus amino acid mixture. Alternatively it could be argued that the increased animal production was the result of a better balance of nutrients absorbed by the host animal, and that the overall efficiency of feed utilization improved because of a reduction in heat production.

The efficiency of feed utilization in terms of metabolisable energy (ME) content of the diet was much greater when the diet was balanced with a bypass protein then would have been predicted for Friesian cattle of this weight. Using standard values for the ME of the ration ingredients the ME of the diet was calculated. The relationship of ME content of the feed and the efficiency of liveweight. Using standard values for the ME of the ration ingredients the ME of the diet was calculated. The relationship of ME content of the feed and the efficiency of liveweight gain per unit of ME intake (figure 3) is highly significantly different to that predicted from classical feeding standards (see Webster 1989), when a bypass protein meal is fed in a diet of treated or untreated straw. These results indicate that the protein to energy ratio is the primary limitation to the efficiency of production. Adding a bypass protein to a diet of low digestibility depresses metabolic heat production or heat increment of feeding (see Blaxter, 1962).

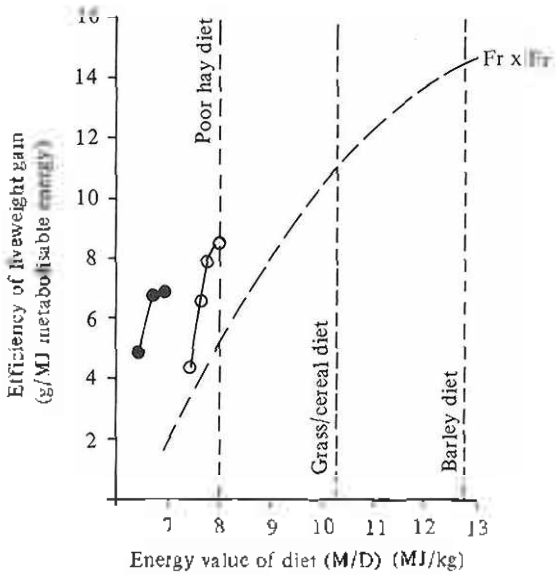

Figure 3. The efficiency of utilisation of straw and ammoniated straw by cattle with free access to a molasses urea block and fed incremental levels of a bypass protein supplement (●) cattle fed the basal diet of straw/rice polishings (○) cattle fed ammoniated straw/rice polishings.

The dotted line is a schematic relationship between diet quality (metabolisable energy/kg dry matter) and food conversion efficiency (g liveweight gain/MJ metabolisable energy intake) (after Webster, 1989). Metabolisable energy (ME) intake and the efficiency of utilization of ME was calculated from the intake of individual components of the diet multiplied by their estimated metabolisable energy content and the liveweight gain of the cattle.

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