COMPARATIVE RESPONSES OF RICE (ORYZA SATIVA) STRAW TO UREA SUPPLEMENTATION AND UREA TREATMENT

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Summary

Twenty five 75% Holstein Friesian cross bred bullocks fed rice straw *(Oryza sativa)* of long form, were fed with the following five treatments.

1. Rice straw, untreated (RS)
2. RS + water (1:1), stored for 24 hours (WRS)
3. RS (100 kg) + urea solution (4 kg urea/100 litre water) and dried (USRS)
4. RS (100 kg) + urea solution (as in 3) stored in wet condition for 24 hours (UWRS)
5. RS (100 kg) + urea solution (as in 3) stored in pit for 21 days (UTRS).

Potential digestibility of treatments of RS was evaluated by monitoring (in vitro) Simulating Rumen like Fermentation (SRLF). The results indicated that Dry Matter Intake (DMI), digestibility of nutrients, N utilization were of the order UTRS > UWRS > USRS > WRS and RS ($p < 0.05$ to $P < 0.01$). SRLF index was high (255.84) for UTRS and least (145.58) for USRS. It was intermediary (199.66) for UWRS. The acetyl content (AC) of UTRS with higher hemicellulose (HCE) digestibility (80.8%) was low compared to UWRS, USRS, RS and WRS. The acetate content was of the order UTRS < UWRS < USRS < WRS and RS thereby indicating that reduction in acetyl content was an index of positive response of urea-treatment of RS. In addition, the ratio of HCE/AC in faeces of UTRS was 0.87 as against the ratios (2.26-2.48) observed in other treatments recording reduction in AC due to urea-treatment. Among the treatments, USRS only supplemented N while UTRS in addition to utilization N, increased the digestibility of structural carbohydrates. Reduction in treatment time from 21 days to 1 day (UWRS) resulted in improvements similar to those of UTRS.

(**Key Words**: Long Form of Rice Straw, Urea Supplementation, Urea Treatment, HF Cross Bred Bullocks)

Introduction

Low Nitrogen (N) (0.38 to 0.75%) and energy content of straw impedes the colonisation of microbes in the rumen resulting in poor digestion. Concerted efforts are therefore directed to break the barriers in straw for mobilising N and energy in the rumen for effective colonisation by microbes. This will result in the utilisation of 80% of potential fermentable energy trapped in cell walls to the ruminants and microbes. Finger millet straw treated with 2% urea and 10% molasses increased its DCP significantly (Venkatachar et al., 1969). Later reports (Devendra, 1978; McLennan et al., 1981) however indicated that supplementation of straw with urea increased its intake and digestibility. In few other instances, urea alone or as supplement did not evoke any positive response (Campling et al., 1962; Faichney 1965; Intaramongkol et al., 1978). However, addition of sucrose or starch depressed the digestibility of urea enriched straws (Faichney, 1978; Mulholland et al., 1971). Use of anhydrous ammonia (Sundstol et al., 1978) or ammoniation through urea (Saadullah et al., 1981; Dolberg et al., 1981; Wanapat et al., 1985) has received great deal of attention as it proved superior over urea-supplementation.

Rice straw is extensively used in feeding cattle in Southern parts of India. It needs to be upgraded nutritionally. The present study is aimed at evaluation of the application modes of urea

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on the nutritive value of rice straw for onward adoption in field.

Materials and Methods

The RS used in the present study was of long form taken from the same stack and was carried out in two stages. In stage 1, ten 75% HF crossbred bullocks of comparable age and weight (BW) were distributed to treatment 1(RS) and 2 (WRS). In stage 2, fifteen 75% HF crossbred bullocks of comparable age and BW were distributed to treatments 3 (USRS), 4 (UWRS) and 5 (UTRS). The details of the treatments carried out are detailed below;

Treatments

1. Rice straw, untreated (RS)
2. RS (100 kg) + water (1:1), stored for 24 hours (WRS)
3. RS (100 kg) + urea supplement (4 kg urea/100 litres water) and dried (USRS)
4. RS (100 kg) + urea solution (as in 3), stored for 1 day in wet condition (UWRS)
5. RS (100 kg) + urea solution (as in 3), stored for 21 days in wet condition (UTRS).

Prior to the studies, the bullocks were fed 1 kg concentrate mixture, 2 to 3 kgs dry straw and green fodder ad lib. The bullocks were dewormed and were given vitamin A injection (3,000,000 IU) prior to initiating the animals into studies. At (3,000,000 IU) prior to initiating the animals into studies. At both stage of study, a preliminary feeding period of 28 days was followed by carrying a metabolism trial of 7 days duration.

Analysis

The dry matter (DM), N, ether extract (EE) and mineral contents (Ca and P) in straw as well as in faeces were determined according to standard procedures (AOAC, 1975). Feed and faecal samples were sequentially analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose (CE), and permanganate lignin (L) according to Robertson and Van Soest (1981). The hemicellulose (HCE) content was calculated as the difference between NDF and ADF. Extract of straws were used for the determination of pH, using Elico pH meter. Water soluble ammonia WNH_3N in the straw was extracted with water (in contact for 30 minutes) and then analysed for WNH_3N by steam distillation of the alkaline solution into boric acid (Dryden and Kempton, 1983). Acetyl (AC) content of straws as well as faeces was determined (DM %) as described by John et al., (1975). Samples (100-200 mg) were suspended in 25 ml of 1M NaOH and incubated at 20 ℃ for 3 days under inert atmosphere (N gas). Insoluble material were removed by centrifugation and volume made up to 50 ml. 5 ml aliquot were acidified with 1.3M H_2SO_4 containing 2M $MgSO_4$ and steam distilled. 75 ml of distillate was titrated with 0.01 N NaOH with phenol red as indicator under a stream of CO_2-free air.

Kinetics of simulated rumen like fermentation (SRLF)

Energy mobilisation in RS by urea application was evaluated by monitoring (in vitro) SRLF by recording gas production rates as proposed by Prins (1987). 1 g of samples (DM) were incubated with 200 ml of 1:1 mixture of strained rumen fluid-buffer (Hungate, 1966) containing 0.5% sodium bi-carbonate in 600 ml plasma bottles, closed with butyl rubber stopper and finally with a screw cap after flushing it with a stream of 100% oxygen free CO_2 gas. Rumen fluid was aspirated from cannulated cows (maintained on concentrate mixture, greens and dry fodder). Gas production was monitored bi hourly by piercing the rubber stoppers with a hypodermic needle. The gas values recorded were corrected for atmospheric pressure using a water-manometer. A blank was prepared without the sample. Kinetics of fermentation was computed as slope of linear regression (cumulated gas against time). The gas production rate during the first 12 hours K_1 is backed-up by fermentation of soluble cell walls (mesophyll cell walls of straws), while the gas production rates beyond 12 hours K_2 assess the slow fermenting carbon pool. Lag-phase if any, was recorded as the period during which no gas is formed or gas production rate is not progressive. For comparative evaluation of the treatments against fermentation kinetics, SRLF index was computed for all K_1 values over K_1 of RS as base (100 units). The statistical analysis of the data was carried out according to the methods given in Snedecor and Cochran (1967).

Results and Discussion

The pH and chemical composition of treated straws are presented in table 1. The intake of DM (figure 1), digestibility of fibre-fractions along with AC content are summarised in table 2. The pattern of N utilisation are compared in table 3. The fractional gas production rate during SRLF with treated straws are compared in table 4, and the changes in gas (%) over untreated straws are compared in figure 2.

pH status of treated straws

pH can be an index of interaction between the treatment, urea-ammoniation and CW content of straws (Amrith Kumar et al., 1988a) RS with a pH ranging from 6.39 to 6.50 increased to 8.77 consequent to treatment, UTRS (table 1). UWRS had slightly higher pH (7.80) than USRS (6.86) indicating the partial hydrolysis of urea in UWRS. Increase in pH during urea-treatment of cotton-straws(Ben-Ghedalia et al.,1980), maize stovers (Dias-Da-Silva et al., 1988), rice straw and sorghum-stovers (Amrith Kumar et al., 1988 a,b) have been reported. Cell wall constituents of fibre-fractions have been reported to buffer the gastro-intestinal tract to maintain desirable pH for microbial activity (Mc Burney et al., 1983).

TABLE 1. pH AND CHEMICAL COMPOSITION OF STRAWS (% ON DM BASIS)

Constituents	RS	WRS	USRS	UWRS	UTRS
pH	6.4	6.4	6.9	7.8	8.8
Organic matter	87.3	84.2	87.5	84.3	86.1
Nitrogen	0.7	0.8	2.1	2.6	2.0
NDF	68.4	69.1	68.6	70.0	74.3
ADF	49.4	54.4	49.7	51.9	55.9
HCE	19.0	14.6	19.0	18.1	18.4
Lignin	5.4	5.8	5.4	5.7	6.3
CE	31.1	33.3	35.0	33.7	39.3
Si	12.7	13.3	9.7	10.1	11.5
Ca	0.2	0.2	0.1	0.2	0.1
P	0.1	0.1	0.1	0.1	0.1
Acetate	4.4	4.7	5.2	4.9	3.9

TABLE 2. DRY MATTER INTAKE AND NUTRIENT DIGESTIBILITY OF STRAWS

Particulars	RS	WRS	USRS	UWRS	UTRS
Live weight (kg)	314-319 (317)	337-340 (337)	311-314 (312)	309-320 (309)	312-318 (314)
DMI (kg/day)	4.4-6.0 (5.4)	4.8-5.9 (5.3)	4.0-6.0 (4.9)	4.6-6.2 (5.5)	5.7-8.5 (7.2)
DMI/100 kg BW (kg)	1.6	1.6	1.6	1.8	2.3
Digestibility (%)					
DM	46.9	44.8	45.3	52.6*	54.4*
OM	53.2	54.7	53.2	60.6*	61.7*
NDF	46.2	45.4	44.8	54.3@	60.5@+
HCE	56.3	54.9	54.1	67.0@	80.8@+
CE	59.3	62.9	61.9	67.9@	77.7@+
AC in faeces (%)	6.5	4.7	6.3	5.3	3.9
HCE/AC (faeces)	2.3	2.4	2.5	2.3	0.9

* $p < 0.05$; @ $p < 0.01$; + $p < 0.01$ (UTRS > UWRS)

TABLE 3. NITROGEN UTILISATION (G / DAY)

Particulars	RS	WRS	USRS	UWRS	UTRS
Intake	37.4	43.1	100.4	162.2	169.0
Faeces	30.4	36.7	32.6	39.4	65.8
% loss in faeces	81.2	85.1	32.4	38.9	24.3
Urine	11.2	11.9	69.6	79.2	41.0
% loss in urine	30.1	27.6	69.3	24.3	48.8
Absorbed	7.0	6.5	67.8	122.7	103.2
Absorption (%)	18.8	15.0	67.6	75.7	61.1
Retained	−4.2	−5.5	−1.8	+43.6	+62.2

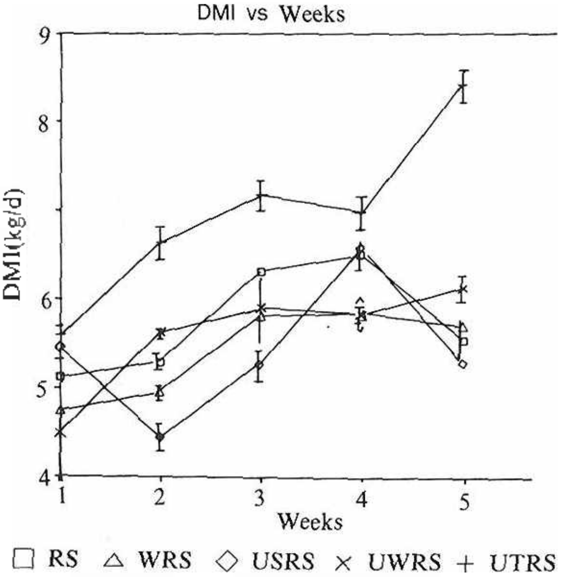

Figure 1. The changes of dry matter intake

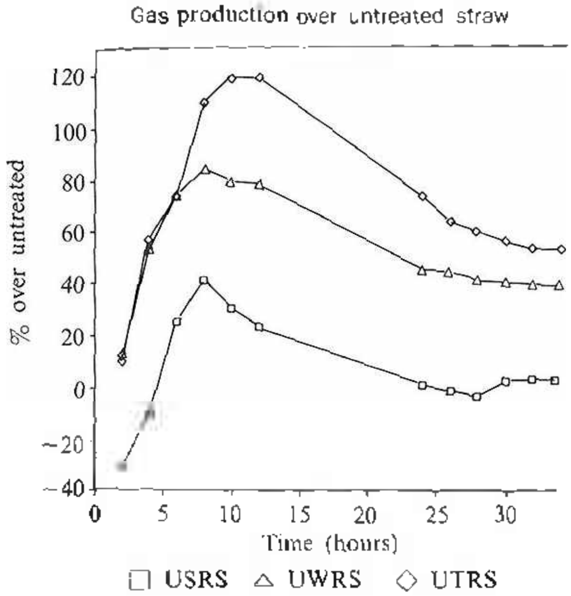

Figure 2. The changes of gas production over untreated straw

TABLE 4. KINETICS OF GAS PRODUCTION* DURING SRLF WITH TREATED STRAWS

Treatment			SRLF Index**	
	K_1	K_2	K_1	K_2
RS/WS	2.9	4.1	100.0	137.8
USRS	4.3	3.8	145.6	130.3
UWRS	5.9	4.9	199.7	166.3
UTRS	7.6	4.9	258.8	168.0

* No lag-time was observed.
** Overbase K_1 of RS (2.94), 100

Composition of straws

The treatments did not affect the gross composition of straws significantly (table 1), while UTRS had higher NDF than USRS or UWRS with consequent effect on cell solubles. The effect on HCE between the treatments UWRS and UTRS did not vary much (table 1). Dias-Da-Silva and Sundstol (1986) have also reported difference in composition of urea treated and un-treated wheat straws, similar to those observed in the present study.

Intake and digestibility

Average DMI (kg) of treated straws over the entire experimental period are compared in figure 1. DMI between the treated straws was of the order UTRS > UWRS > USRS, RS and WRS which was significant ($P < 0.05$). The digestibility of DM, OM, NDF, ADF, CE and HCE of these corresponding straws indicated that the values obtained for UTRS and UWRS were highly significant ($p < 0.05$ to < 0.01). The digestibility of the nutrients obtained for UTRS was significantly higher ($p < 0.01$) compared to UWRS (table 2). The treatment, USRS did not improve the digestibility of nutrients over those of RS and WRS (table 2). Dunlop and Kellaway (1980) attributed increased intake of straw to increase in potentially digestible CW and also due to shift in slow digesting CW-pool compared to fast digesting CW pool. Further, higher solubilisation of HCE also increased voluntary intake (Jackson, 1978) which is apparent in UTRS and UWRS (table 2). Earlier studies on urea-treatment of straw have indicated increased intake of straw resulting from increased digestibility of fibre fractions (Soliman et al., 1979). Overall improvements gained by urea-treatment of other substrates have also been reported by earlier workers (Dias-Da-Silva and Sundstol, 1986; Saadullah et al.). However, in the present study it is clear that urea treated straw stored for 1 day (UWRS) increases DMI and digestibility similar to that stored for 21 days (UTRS).

Nitrogen utilisation

The initial N content of RS and WRS was 0.75% which increased to 2.06% in USRS, 2.56 % UWRS and 2.00% in UTRS (table 3). It is apparent that 30% of the added N was lost from USRS, 3% from UWRS and 33% from UTRS. The losses of N from UWRS and UTRS would have continued prior to their ingestion by animals, and hence, N intakes are over-estimates.

The release of ammonia (NH_3) consequent to urea treatment in straws was monitored as an index of urea hydrolysis. During treatment, (NH_3) formation was in traces at the 6th hour which steadily increased to 1.0 and 1.1% by 24 hours. Total NH_3 production during 72 hrs was 1.39% and further incubation did not promote any considerable increase in NH_3 content. The WNH_3-N content of UTRS was 1.39% compared to 1.1% of UWRS. Of the total N added, 74% was in the (WNH_3N) fraction of UTRS, compared to 59% of UWRS. The WNH_3N content recorded for UTRS in the present study is higher than those reported (53 to 65%) by earlier workers for other straw systems (Dryden and Kempton, 1983; Surdon and Chesson, 1983; Ibrahim et al., 1986). In a recent study, Amrith Kumar et al., (1988a) have reported increased WNH_3N fraction (65 to 80%) with increased levels of urea (4 to 6%). It is significant that UWRS treatment while acting partly as supplement, has exerted some alkaline influence on CW, indicating its superiority over USRS. The merit of this treatment needs further evaluation.

Intake of N^{-1} day was higher in UTRS followed by UWRS and USRS (table 3). The higher N intake in UTRS is evidently due to significantly higher DMI ($p < 0.05$). The loss (%) through faeces and urine in animals fed UTRS was 38. 92 and 24.26% respectively, being lower than the values recorded for USRS (table 3). However, loss of N through urine was much lower for UWRS indicating partial hydrolysis of urea could have reduced the urine N loss, resulting in higher N retention (table 3).

Kinetics of SRLF

Rate and extent of substrate digestion by microflora are related to energy pool of substrates used. Fast kinetics approach built on in vitro technique (SRLF) evaluates the potential pool of substrates to signify the rumen turnover. Among the treatments, UTRS unlocked the fast fermenting pool in greater magnitude over UWRS and USRS. The K_1 values of UTRS was significantly higher ($p < 0.01$) over those of UWRS and USRS (table 4). However, K_2 the slow fermentable portion of carbon pool of both UTRS and UWRS are comparable (table 4). Menke et al. (1979) reported low gas production (20 ml) from 200 mg of ground wood, while over 70 ml of gas was produced from highly digestible substrates during 24 hrs. These rates of gas production had correlation to OMD measured (in vivo) in sheep.

SRLF index of K_1 recorded for UTRS (255.4) (table 4) is by far a higher value recorded over those reported for similar treatment on rye, wheat and barley straws was 117.7, 117.5 and 105.1 respectively (Prins, 1987). Varying levels of urea (4 to 6%), Amrith Kumar et al. (1988 a) did not show any significant change in the fermentation kinetics of RS.

Higher (K_2) (4.02) values of RS observed over (K_1) (2.94) in this study demonstrated the poor carbohydrate pool staggering the fermentation.

However, with time, the slow but progressive microbial colonisation sustain fermentation for microbes to thrive. This is adequately demonstrated by low DMI values by animals fed with RS (table 2). The pattern of SRLF index (table 4) worked out was a desirable accomplishment of treatment which compensated for increased turnover rates (figure 2) through higher fermentation rates (Hungate, 1966). Fermentation gas production rates correlated with in vivo OMD (Menke et al., 1979) and also values with rates of VFA production, the major energy source of ruminants (Hungate, 1965). Further, the absence of lag-time in SRLF observed in the present study with or without treatment in contrast to those reported (Prins, 1987) could be attributed to variations in the rumen ecosystems. USRS treatment repressed fermentation kinetics during the first 5 hrs while UWRS treatment did not (figure 2) indicating the beneficial endowment of partial urea-hydrolysis in unlocking the energy pool. The rapid fermentation kinetics associated with urea-hydrolysis (UTRS or UWRS) could be ascribed to the fragility, the physical change of fibrous substrates manifested due to alkalinity (Zorilla-Rios et al., 1985).

Digestibility and acetyl content of straws

Maturity of grasses promotes acetylation accompanied with a fall in digestibility of pentosan fractions (Waite et al., 1964). Acetyl groups are chiefly located on hemicellulose fraction of grass and cereals, while in root vegetables a large part is associated with the pectin fraction (Bacon et al., 1975). Morris and Bacon (1977) observed no preferential loss of acetyl groups of grass cell walls during ruminal digestion. Removal of all acetyl groups from barley straw with increasing levels of alkali, promoted digestibility (Bacon, 1979; Bacon and Gordon, 1980). In the current study, ratio of HCE to AC in faeces reduced from 2.26 in RS to 0.87 in UTRS (table 4) with concomitant increase in OMD. The alkaline (NH_3) environment during 21 days of ensiling with urea (UTRS) has partly neutralised the alkali labile acetyl groups leaving behind highly substituted fraction of HCE which still impedes digestibility (partially). The HCE/AC ratio in faeces was negatively correlated to digestibility irrespective of the nature of treatment; DMD −0.53; NDF −0.67; ADF −0.62; HCE −0.77; CE −0.60; ($p < 0.01$) and OMD −0.43 ($p < 0.05$) of acetyl groups (75%) during ammoniation with the residual acetyl group (25%) resistant to digestion. In contrast the acetyl groups of untreated straws (80%) were water insoluble, highlighting the beneficial effects of urea-treatment.

Conclusion

Urea treatment (4%) of rice straw resulted in significant improvement in its intake and digestibility. In addition, there is scope to reduce the storage period less than 21 days to gain similar response.

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