# PHYSIOLOGY OF DIGESTION OF UREA-TREATED RICE STRAW IN SWAMP BUFFALO

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## Summary

Four rumen-fistulated swamp buffaloes steers were used in a change-over experiment. This experiment was designed to provide a comparison of the effect of urea-ammonia treatment of rice straw with untreated rice straw. Nitrogen, mineral and trace elements were supplied at adequate levels to both diets in order to overcome deficiencies which may have otherwise confounded a direct comparison. There was a 46% increase in the intake of digestible organic matter (OM) with the urea-ammonia treated diet. This was contributed by a 17% increase in the digestibility of OM and a 25% increase in the voluntary intake of OM. Of the cell wall fraction, the digestibility of hemicellulose increased by the greatest amount (26%). There was an increased rate of passage of particulate matter out of the rumen for the treated straw, along with the increased rate of OM fermentation resulted in a 9% decrease in the amount of digesta dry matter (DM) contained in the rumen. The volatile fatty acid (VFA) pool in the rumen was 24% higher for the treated diet.
**(Key Words:** Rice Straw, Urea-Treatment, Digestion, Swamp Buffalo)

## Introduction

While reports have been made for improved liveweight gain and milk production in cattle and buffalo fed urea-ammonia treated rice straw (Nurazzanal Khan and Davis, 1981; Wanapat et al., 1984), negative responses have also been reported (Van Soest and McBurney, 1985). To date all the experiments dealing with the utilization of urea-ammonia treated rice straw have been of a production nature. These type of experiment are not designed to furnish explanations for observed responses. Hence, the present experiment was designed to add some fundamental information to this important area of ruminant nutrition research.

## Materials and Methods

Four rumen fistulated swamp buffalo (mean liveweight 140 kg) were used in change-over experiment. Prior to the experiment, they were vaccinated and drenched against contrageous diseases, liver fluke, intestinal parasites, and injected with vitamin A, $D_3$ and E.

The rice straw was pre-treated with urea by adding 5% (w/w) urea dissolved in water (50: 50, water to straw) to the straw. The straw was then covered with plastic and matured for 10 days. The two diets were untreated rice straw with urea (3% w/w), mineral and trac alements (see table 1) dissolved in water (to give approximatedly the same moisture content as the treated

TABLE 1. MINERAL AND TRACE ELEMENT COMPOSITION[1]

| Mineral and trace element | Concentration |
|---|---|
| | (g/kg Straw DM) |
| Dicalcium ortho phosphate | 17.3 |
| Magnesium sulphate | 10.0 |
| Potassium chloride | 7.3 |
| Sodium chloride | 4.7 |
| | (mg/kg Straw DM) |
| Iron sulphate | 250 |
| Zinc sulphate | 250 |
| Manganese sulphate | 120 |
| Copper sulphate | 20 |
| Potassium iodide | 1.7 |
| Cobalt sulphate | 0.5 |

(Underwood, 1977; ARC, 1980).

N:S ratio approximately 10:1.

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straw) and sprikled onto the straw at the time of feeding. The other diet was the urea-ammonia pre-treated rice straw which was fed direct from the stack with the addition of minerals and trac elements. The control and treated diets were to be equivalent in their nitrogen, minerals, trac elements and moisture content.

Measurement were made of voluntary OM and water intake, rate of degradability of OM in the rumen, rate of passage of fluid particles from the rumen, the amount of water and DM in the rumen and partical size distribution, pH, concentration of ammonia and VFA in rumen fluid and the apparent disgestivility of OM and fiber in the overall gastrointestinal tract (GIT).

After first adapting the buffalo to the straw diet for three weeks, voluntary OM intake was measured over a period of 2 days. The diets were fed twice daily at approximately 20% above the precious days intake. Dry matter analysis of feed, feed refusals, feed spillage and feces was carried out daily. Samples were also bulked and frozen for subsequent analysis of chemical composition.

The rate of degradability of untreated and treated straw was measured using synthetic fiber bags ("Nytal" screen cloth. No. 325-44, pore siz e 20 microns). Duplicate sets of bags containing either of 1.8 mm) were placed in the rumen of buffaloes if intervals of degradable OM (K)* was calulated as the slope of the regression between the natural log of the amount of degradable OM remaining in the bag versus time of incubation of the bag within the rumen. The time for half the degradable OM to disappear (T½) from the bags was calculated as T½ = 0.693/k. (Ørskov et al., 1980).

The rate of passage of fluid from the rumen was estimated by giving a single does of 50 g. of Cobalt EDTA into the rumen. A total of 20 strained rumen fluid samples were collected at various intervals of time over a period of three days. The samples were acidified and stored in a freezer until required for analysis. Cobalt was analysed by dilution with water direct aspiration on the atomic absorption spectrophotometer (AAS).

The rate of passage of particulate matter from the rumen was estimated using a single does of 60 g. of Chromium mordanted fiber. The fiber was mordanted using the technique of Uden et al. (1980) after first grinding and double sieving the straw to eliminate fine and large particles (screen sizes 0.5 and 2.0 mm, mean straw particle length 6.8 mm). A total of 22 particle samples were collected from the rumen at various intervals over five days. The samples were oven dried and stored until required thermal ashing with the addition of potassium hydroxide and potassium phosphate.

Measurement of the rumen fluid and dry matter content were made by emptying the rumen and weighing the content. Samples were taken for dry matter analysis and also for particle size distribution studies. The rumen was emptied once per day for four days at either 1000 or 1400 hours. Particle size distribution was measured using the wet sieving technique (screen apertures 0.15, 0.3, 0.6, 1.2, 2.4 and 4.8 mm).

For analysis of rumen pH, ammonia and VFA concentration, samples were collected at 08:00, 13:00 and 16:00 hours daily for six days. Individual samples were immediately read for pH with the remainder of the sample being acidified until required for ammonia and VFA analysis. Rumen ammonia was measured using the phenol hypochlorite colourimetric procedure and total VFA's were estimated by steam distillation and titration with sodium hydroxide. (Chanthai et al., 1987).

The overall apparent digestibility of straw nutrients was measured by the total collection of feces. In comparison. acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) were analysed by the method of Goering and Van Soest (1970) while nitrogen, ash and acid insoluble ash (AIA) were analysed following the precedure of AOAC (1972). *In vitro* dry matter digestibility (IVDMD) was measured using the cellulase method. (McLeod and Minson, 1978).

## Results and Discussion

Chemical composition analysis of the straw diets indicated that the ADF, ADL and AIA concentration increased while the hemicellulose fraction decreased due to the urea-ammonia treatment (table 2). This trend is consistent with the3 results reported by Van Soest and McBurney (1985). The nitrogen concentration was similar for the two diets. They both supplied approximately 26 g nitrogen per kg of OM fermented in

TABLE 2. CHEMICAL COMPOSITION AND IVDMD OF UNTREATED AND UREA-TREATED RICE STRAW (% DM BASIS)

| Measurement | Untreated straw[1] + urea | Urea-ammonia treated straw (5%, w/w) |
|---|---|---|
| | (%) | |
| Organic matter (OM) | 85 | 86 |
| Crude protein (CP) | 7.5 | 7.4 |
| ADF (cellulose and lignin) | 51 | 53 |
| NDF-ADF (hemicellulose) | 24 | 23 |
| NDF (cell wall) | 75 | 76 |
| ADL (lignin) | 2.7 | 3.4 |
| AIA | 9.8 | 10.4 |
| IVDMD | 43 | 52 |

[1] Straw was fed after the addition of urea.

the rumen. There was an increase of 9 percentage units in the IVDMD of treated straw (43 versus 52) using the cellulase technique.

It was observed that both the intake of OM and the overall apparent digestibility of OM increased significantly due to straw treatment (2.63 versus 3.28 kg/d and 60 versus 70% for intake and digestibility, respectively). This resulted in a very marked increase (46%) in the total digestible OM intake (table 3). While there was a large straw in the total cell wall digestibility of the treated straw (60 versus 72%), it was the hemicellulose component which showed the most marked increase in digestibility (68 versus 86%). It appears that most of the ligno-hemicellulose bonds were cleaved by the urea-ammonia treatment, rendering the hemicellulose soluble and available for microbial fermentation. The increase in mineral absorption from the gastro-intestinal tract (GIT) (40 versus 46%) is consistent with

TABLE 3. THE EFFECT OF UREA-TREATMENT OF RICE STRAW ON INTAKE AND DIGESTION

| Measurement | Untreated straw + urea | Urea-ammonia Treated straw | Urea-ammonia % Increase | Sig. |
|---|---|---|---|---|
| Voluntary DM intake (kg/d) | 3.06 | 3.82 | 25 | ** |
| Voluntary OM intake (kg/d) | 2.63 | 3.28 | 25 | ** |
| Voluntary water intake (l/d) | 16.5 | 16.7 | 1 | NS |
| Digestible DM intake (kg/d) | 1.68 | 2.48 | 48 | ** |
| Digestible OM intake (kg/d) | 1.58 | 2.30 | 46 | ** |
| T½ of OM disappearance from nylon bags (h) | 14.9 | 11.8 | −26 | ** |
| Potetial DM degradability in rumen (% original DM)[1] | 69 | 77 | 12 | ** |
| Apparent DM digestibility (%) | 55 | 65 | 18 | * |
| Apparent OM digestibility (%) | 60 | 70 | 17 | * |
| ADF (%) | 56 | 66 | 18 | ** |
| Hemicellulose digestibility (%) | 68 | 86 | 26 | ** |
| NDF (%) | 60 | 72 | 20 | ** |
| Mineral absorption (%) | 40 | 46 | 15 | * |
| AIA recovery (%) | 94 | 75 | −27 | ** |

* $p < .05$, ** $p < .01$, [1] Measured in nylon bags; 96 h. incubation.

the increase in DM digestibility. The recovery of AIA was reduced from 94% to 75% (table 3) as a result of the straw treatment. Possibly some of the AIA may have been solubilised due to the straw treatment and absorbed in the GIT. When a correction was applied for this reduced recovery of AIA, the calculated digestibility was similar to that measured by the total collection method.

The increase in fermentation rate of the treated straw was evident in the in sacco study (see figure 1) where the rate of disappearance of degradable OM increased from a T½ of 14.9 hours for untreated straw to T½ of 11.8 hours for the treated straw. In addition, there was a higher concentration (61 versus 82 m mole/l) and pool size (1.9 versus 2.3 moles) of VFA's in the rumen of those animals consuming the treated straw (table 4).

The enchanced rate of passage of particles through the rumen of those animals consuming the treated straw was demonstrated by the reduction in mean retention time of chromium mordanted fibers from 85 to 58 hours for the untreated and treated straw diets, respectively (table 4). Naturally the Cr mordanted fibers would have underestimated the actual rate of dietary particle outflow texture and the fact that they were non-degradable in the rumen. However, this technique does provide a good comparative

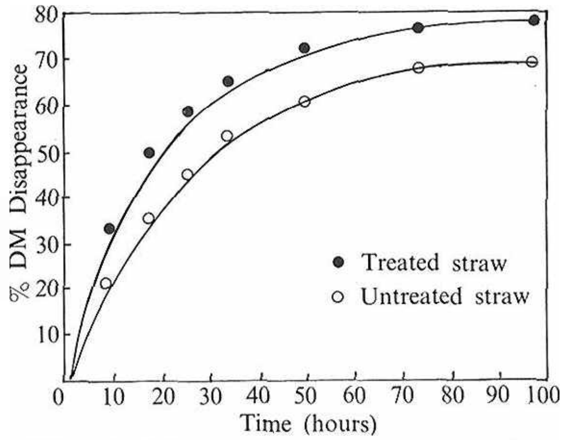


Figure 1. Disappearance of DM from nylon bags at varying incubation times in the rumen.

measure of the rate of particle outflow from the rumen. In addition, the particle size distribution study indicated that there were fewer small particles (mean length less than 3.0 mm) in the rumen of those animals consuming the treated straw. This enhanced rate of passage of particles from the rumen of these animals consuming the treated straw may have been due to two factors. Firstly, the texture of the straw is altered when it is urea-ammonia treated, which may have allowed particles of greater length to pass through the reticulo-omasal orifice. Secondly, when animals consume untreated straw, their rumens tend to

TABLE 4. THE EFFECT OF UREA TREATMENT OF RICE STRAW ON VARIOUS RUMEN MEASUREMENT

| Measurement | Untreated straw + urea | Urea-ammonia Treated straw | % Increase | Sig. |
|---|---|---|---|---|
| Mean retention time of Co EDTA in rumen (h) | 16 | 16 | 0 | NS |
| Mean retention time of Cr mordanted fiber in rumen (h) | 85 | 58 | −32 | ** |
| Volume of water in rumen (l) | 31.0 | 28.7 | 7 | NS |
| DM content of rumen (kg) | 4.60 | 4.18 | 9 | ** |
| pH of rumen fluid | 6.5 | 6.5 | 0 | NS |
| Ammonia concentration in rumen fluid (mg/l) | 183 | 98 | −46 | ** |
| Rumen ammonia pool size (g) | 5.65 | 2.81 | 50 | ** |
| VFA concentration in rumen fluid (m mole/l) | 61.1 | 81.8 | 34 | ** |
| VFA pool size in rumen (moles) | 1.89 | 2.34 | 24 | ** |

* $p < .05$, ** $p < .01$.

become impacted (see rumen DM content, table 4). This reduces the movement of the particles within the rumen and hence the opportunity for particles to pass out of the rumen.

Contary to the suggestion of Van Soest and McBurney (1985) that osmotic effects cause an increase in water treated diet, this effect was not evident in the present experiment. Both the rate of passage of water from the rumen (table 4) and the voluntary water intake (table 3) were similar for the untreated and treated diets.

The smaller concentration of rumen ammonia associated with the treated straw diet (98 versus 183 mg. $NH_3$/l) may be explained by the following reasons. Firstly, wheen urea is added to the untreated straw at the time of feeding it is rapidly hydrolysed in the rumen to free ammonia. However, because the rate of release of ammonia from the urea would exceed the rate of uptake by microbes for protein synthesis, it would accumulate in relatively high concentrations in rumen fluid. However, with the treated straw, some of the ammonia becomes bond to the fiber, such that after remove of the straw from the stack, approximately 55% of the added urea nitrogen is retained following aeration and drying. It may be postulated that the reduced rate of release of this bond ammonia in the rumen enables a more efficient uptake by microbes for protein synthesis. In adition, because of the increased rate of OM fermentation with the treated straw, there would be a concomitantly higher requirement for ammonia for microbial protein synthesis. Hence. less ammonia would accoumulate in rumen fluid.

On the other hand, Van Soest and McBurney (1985) stated that from between 0-66% of additional N supplied for ammoniation may be contained in the acid detergent indigestible pool, which would make it unabailable for microbial fermentation. Therefore, the extent of release of ammonia in the rumen would be reduced leading to a lower concentration of ammonia in the rumen.

## Conclusions

The present experiment clearly shows that the increased intake of OM resulting from the urea-ammonia treatment of rice straw was facilitated by both an increased rate of OM fermentation in the rumen as well as by an increased rate of passage of particles from the rumen. In addition to urea-ammonia treated rice straw providing adequate nitrogen for microbial protein synthesis, it very markedly increases fiber digestibility and total intake of digestible of OM.

## Recommendations

The technique of treating rice straw is simple, demands little labour and is relativeely cheap. This process enables rice straw to be upgraded from a sub-maintenance to a maintenance ration. In addition to improving the nutritive value of the rice straw, it also reduces the deterioration of the straw due to mould growth during the wet season.

The use of urea-ammonia treated rice straw has a special role to play in the newly developing beef and dairy enterprises in the drier less favourable regions of Thailand where natural vegetation is inadequate for livestock production.

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## Literature Cited

Agricultural Research council (ARC). 1980. The Nutrient Requirements of Ruminant Livestock. Pub Comoinwealth Agricultural Bureau, U.K.

AOAC. 1972. *Official Methods of Analysis (12th Ed.)* Assoc. Offic. Analyt. Chem., Washington, D.C.

Chanthai, S., M. Wanapat and C. Wachirapakorn. 1987. Rumen ammonia-N and Volatile fatty acid concentrations in cattle and buffalo given rice straw based diet. Proc. of the 7th AAFARR Workshop *Net work (Ed. R. M. Dixon), held at Chieng Mai* Phucome Hotel, Chieng Mai, Thailand, June 2-6. IDP, Canberra.

Goering, H. K. and P. J. Van Soest. 1970. Forage

Fibre Analysis. U.S. Dept. Agric. Handbool No. 379.

McLeod, M. N. and D. J. Minson. 1978. The accuracy of the pepsin-cellulase technique for estimating the dry matter digestibility *In vivo* of grasses and legumes. Anim Feed Sci and Tech. 3:277.

Nurazzanal Khan, A. K. M. and C. H. Davis. 1981. Effect of treating paddy straw with ammonia (generated from urea) on the performance of local and cross-beed livestock Production from Minimum Land. Held in Bangladesh Haque and M. Saadullah). pp. 168-180.

Ørskov, E. R., F. D. Dep Hovell and I. McDonald. 1980. The use of nylon bag technique for evaluation of feedstuffs. Trop. Anim. Prod. 5:195.

Uden, P., P. E. Colucci and P. J. Van Soest. 1980. Investigation of Chromium, Cerium and Cobalt as markers in digesta rate of passage studies. J. Sci. Food Agric. 31:625-632.

Underwood, E. J. 1977. *Trac elements in humen and animal nutrition*. pp. 56-127. Academic Press, New York.

Van Soest, P. J. and M. I. McBurney. 1985. Problems evaluating the nutritive values of trated straw. Proc. 3rd AAAP Animal Science Congress "Feeding Systems of Animals in Temperate Areas". Held in Seoul, Korea.

Wanapat, M., P. Sriwattanasombat and S. Chanthai. 1984. The utilization of diets rice straw and urea-ammonia treated rice straw and water hyacinth. Proc. Third Annual Workshop on "The Utilization of Fibrous Agricultural Residues as Animal Feeds". Held in Sri Lanka (Ed. P. T. Doyle) pp. 156-165. ACIAR, Canberra, Australia.