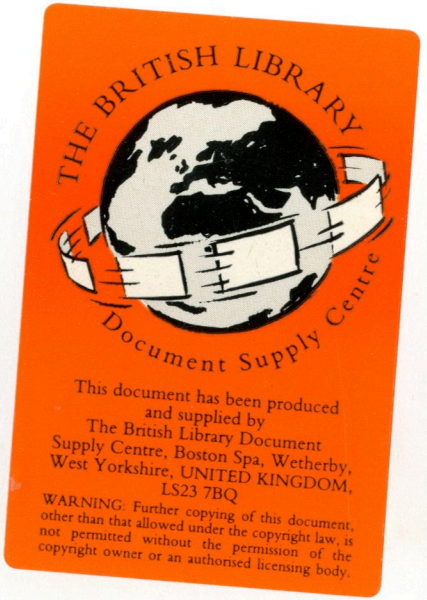

fractions and degradability of different varieties of oat and wheat straws. Anim. Prod., 47: 387–392.

Sundstol and Owen, E. (Editors), 1984. Straw and Other Fibrous By-products as Feed. Elsevier, Amsterdam.

Thomson, E.F. and Ceccarelli, S., 1991. Progress and future directions of applied research on cereal straw quality at ICARDA. In: G. Galletti (Editor), Production and Utilization of Lignocellulosics: Plant Refinery and Breeding, Analysis, Feeding to Herbivores, and Economical Aspects. Elsevier, London, pp. 249–264.

Tilley, J.M.A. and Terry, R.A., 1963. A two stage technique for the in-vitro digestion of forage crops. J. Br. Grassl. Soc., 18: 104–111.

Tuah, A.K., Lufadeju, E. and Orskov, E.R., 1986. Rumen degradation of straw. I. Untreated and ammonia-treated barley, oat and wheat straw varieties and triticale straw. Anim. Prod., 43: 261–269.

White, L.M., Hartman, G.P. and Bergman, J.W., 1981. In vitro digestibility, crude protein, and phosphorus content of straw of winter wheat, spring wheat, barley and oat cultivars in Eastern Montana. Agron. J. 73: 117–121.

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Influence of urea treatment or supplementation on degradation, intake and growth performance of goats fed rice straw diets

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Abstract

Rice straws were either treated with urea (50 g urea in 600 ml of water) and stored for 2 weeks or sprayed with urea solution (20 g urea in 600 ml of water kg^{-1} DM straw) and fed immediately. These two basal diets were supplemented with rice bran (RB), mineral and vitamin premix, common salt, with or without fish meal (FM) to form four treatment diets.

In situ degradability studies and chemical analyses were used to test the effectiveness of urea treatment or supplementation in a completely randomized design using three fistulated sheep fed a standard diet. Animal response when fed urea-treated rice straw (UTRS) or urea-supplemented rice straw (USRS), supplemented with RB with or without FM, was studied using 32 growing female dairy goats in a completely randomized design. Growth rate and dry matter intake (DMI) were recorded for 90 days.

The results showed that N content increased from 7.0 (untreated rice straw (URS)) to 17.4 and 18.6 g N kg^{-1} DM for USRS and UTRS, respectively. The rate of DM degradation was significantly ($P<0.01$) increased from 1.9% (URS) and 3.5% (USRS) to 4.5% h^{-1} (UTRS). The 48 h DM degradability was improved from 42.5% (URS) and 55.1% (USRS) to 65.7% (UTRS).

The effective degradability (ED) calculated assuming passage rates of 2% h^{-1} and 4% h^{-1}, respectively, were 39.6% and 31.3% (URS), 45.3% and 37.3% (USRS) and 53.6% and 44.1% (UTRS).

Urea treatment increased daily straw DMI to 59.3 g $kg^{-1}W^{0.75}$ compared with 23.1 g for USRS. This corresponds to 2.9% and 1.2% of body weight, respectively. The total DMI was increased from 45.8 (2.3% of body weight) to 89.4 (4.3% of body weight) g $kg^{-1}W^{0.75}$ day^{-1} for USRS and UTRS based diets, respectively. Both urea treatment and FM supplementation significantly ($P<0.001$) increased average daily gain (ADG) from 3.3 ± 1.5 (USRS) to 36.9 ± 1.5 g day^{-1} (UTRS) and from 13.0 ± 1.5 g day^{-1} (USRS+FM) to 49.1 ± 1.5 g day^{-1} (UTRS+FM).

It was concluded that urea treatment promoted DMI with a corresponding increased growth performance by goats due to increased rate and extent of degradation of UTRS compared with USRS. Similarly, when a small amount of FM was supplemented increased weight gains and feed efficiency were observed on both USRS and UTRS based diets.

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Introduction

For the past two decades there has been a global search for alternative feed resources for sustainable animal productivity (Owen and Jayasuriya, 1989). The importance of crop residue as feed for ruminants, especially during the dry season, has been recognized by farmers who face a number of constraints on their appropriate improvement and utilization (Wanapat, 1990).

The main nutritional constraints on rice straw as an animal feed are its slow rate of digestion and low nitrogen (N) content. Urea treatment increases N content as well as intake (Tuen et al., 1991) and extent and rate of digestion (Ibrahim et al., 1989). Feeding trials with sheep have shown that animals fed urea-treated and urea-supplemented rice straw ate more and grew faster than animals receiving untreated straw (Djajanegara and Doyle, 1989). However, it was not clear whether this was due to an increase in N per se or to chemical changes in the straw arising from the effect of NH_3 released from the urea. There is also limited information on the ability of dairy goats to utilize straw relative to other ruminant species, such as sheep. Furthermore, the exact mechanism by which a small amount of FM supplementation to straw diets promotes a marked increase in weight gain is not clearly understood. An experiment was therefore carried out to assess the intake and growth performance of goats fed urea-treated or urea-supplemented rice straw with or without fish meal supplements.

Materials and methods

Feeds

Rice (*Oryza sativa*) straw, var. Subarmati, was collected from Dakawa Rice Farm immediately after the rice harvest (untreated rice straw (URS)). Urea (46% N) of fertilizer grade was used as a source of NH_3 for supplementation and treatment of the rice straw.

Urea-treated rice straw (UTRS) was made by urea concentration of 50 g urea kg^{-1} DM straw (w/w). The moisture level was 600 ml of water kg^{-1} DM straw according to ICAR (1985). The rice straw (whole) was spread on a concrete floor. Urea solution was sprayed on the straw using a watering can while the straw was thoroughly mixed using a hay fork to ensure uniform application of urea and moisture content. The rice straw sprayed with urea solution was placed in a silage pit and covered with a sheet of polythene. Treatment time was 14 days. The minimum and maximum ambient temperatures were between 20–24 and 31–34°C. The minimum and maximum relative humidity were between 40–45 and 85–90%.

Urea-sprayed rice straw (USRS) was made by urea concentration of 20 g urea kg^{-1} DM straw (w/w), using the same amount of water and the same

technique as for urea-treated rice straw. The sprayed rice straw was fed immediately after urea spraying. At the same time, samples for chemical analyses and rumen degradability studies were collected and dried at 60°C for 48 h. Rice bran, fish meal, common salt and a vitamin and mineral premix were bought from the local feedstuffs company.

Chemical analyses

All straws and concentrates used in the experiment were analysed for DM and ash according to AOAC (1990) procedures. The Kjeldahl was used for N determination. Cell-wall constituents (CWC), such as ADF, NDF, hemicellulose, cellulose, lignin and acid-insoluble ash (AIA, which is mainly silica) were determined by the method of Goering and Van Soest (1970).

Degradability experiments

Degradability characteristics of straws (i.e. untreated (URS), urea-sprayed (USRS), and urea-treated (UTRS)) were determined in situ using three rumen fistulated sheep fed a standard diet (Table 1). Samples were ground to pass a sieve size of 2.5 mm. One nylon bag (7.5×10 cm size and mean pore size of 60 μm) containing 2 g of each sample was used per animal for each incubation time. Incubation intervals were 0, 6, 12, 24, 48, 72, 96 and 120 h. The 0-h incubation was obtained by soaking the bags for 2 h in water. All bags were washed thoroughly in tap water until the water was clear after each incubation time. Subsequently, the bags were dried at 60°C for 48 h. Standard AOAC (1990) procedure was used to determine the DM of the residue.

Calculations

Degradation of DM

The degradability of the DM of the samples was calculated from the disappearance of DM from the bags after rumen incubation and washing. The

Table 1
The standard diet for degradability studies (Experiment 1)

Basal diet	Concentrate
Brachiaria brizantha hay (fed at 35 g kg^{-1} $W^{0.75}$)	One part rice bran Two parts cotton seed cake meal Fish meal given at 50 g (FM) kg^{-1} DM of hay Common salt 1% of the DM straw
Roughage to concentrate ratio 70:30	

degradability constants of straw were calculated according to the mathematical model of Ørskov and McDonald (1979):

$$p=a+b(1-e^{-ct}) \quad (1)$$

where: p is the actual degradation after time t; a is the soluble fraction assumed to disappear instantly (intercept of the degradation curve at time zero); b is the insoluble but potentially degradable component of the feed; and c is the rate constant at which b is degraded.

The calculation for the degradability constants was executed using the SAS program Proc NLIN (SAS, 1988).

Effective degradability (ED)

Effective degradability (ED) was calculated assuming passage rates of 2 and 4 % h^{-1} and the formula of Ørskov and McDonald, (1979):

$$ED=a+(b(c/(c+k))) \quad (2)$$

where a, b and c are the constants from Eq. (1) and k is the passage rate.

Feed intake and growth experiments

Animals

Thirty-two growing (Norwegian × Saanen × Tanzania local) female goats with mean initial body weights of 12.6 ± 1.6 kg (8–9 months of age) were used to assess intake and growth. The animals were divided into their respective treatment/replication pens of four goats and group fed (straw) and fed individually (concentrate). All animals were effectively dewormed before the start of the experiment.

Diets

The basal diets consisted of either urea-supplemented rice straw (USRS) (Treatments 1 and 2) or urea-treated rice straw (UTRS) (Treatments 3 and 4). Rice bran (RB), common salt, mineral and vitamin premix were supplemented to all treatment diets, while fish meal (FM) was supplemented to Diets 2 and 4. Treatment diets were as follows: (1) untreated rice straw + urea (USRS) + RB; (2) untreated rice straw + urea (USRS) + RB + FM; (3) urea-treated rice straw (UTRS) + RB; (4) urea-treated rice straw (UTRS) + RB + FM.

Fish meal was intended to be supplied at a level of 50 g kg^{-1} DM straw, and RB to be supplied to meet a straw to concentrate ratio of 70:30. Owing to day-to-day variation in straw DM intake the actual intakes deviates from this (see Table 4).

Feeding

Regardless of their treatment diets animals were fed straw diets containing 20 g urea in 600 ml of water kg^{-1} DM straw for 10 days before the start of the adaptation period to expose the animals to straw diets. Then the animals were given their respective treatment diets for 14 days as an adaptation period.

During the experimental period the animals were fed all supplements and straws in two equal amounts daily at 09:00 and 15:00 h. Fresh food was introduced each feeding time. The feeding strategy was to feed straws ad libitum so that the refusal was approximately 20% of the amount offered. The concentrate was fed to give a straw to RB ratio of 70:30 plus 50 g FM kg^{-1} DM straw. The animals had free access to water. The growth experiment lasted for 90 days.

Measurements of feed intake and weight gain

Food offered and that refused was weighed every day and a sample collected and analysed for DM (i.e. put in an oven at 60°C for 48 h). The values were used to estimate the DM intake of straws.

Initial and final body weights were estimated by using the mean weights on three consecutive days at the beginning and end of the experiment to ensure accuracy. In between the animals were weighed every fortnight.

Experimental design and statistical analysis

Experimental design

The experiments followed a complete randomized design, as described by Snedecor and Cochran (1989). One bag per feed sample per incubation time, repeated in three sheep was used. All experimental feed samples for the same incubation time were incubated at the same time to avoid period variations. The animals in the feed intake and growth experiment were allocated randomly to four treatments of eight goats, then replicated twice within each treatment to get two observations per treatment from the average of group fed straw intake and subsequent total DMI. Individual observations were measured for 32 goats for growth, FM and RB intake.

Statistical analysis

General Linear Models (GLM) procedures (SAS, 1988) were used to test the difference in degradability characteristics of URS, USRS and UTRS and the difference between the four treatment diets on intake and growth performance of goats. The efficiency of the analysis was improved using the initial body weight as a covariate.

Results

Chemical analysis

The chemical composition of the straws and concentrates used is given in Table 2. Urea treatment increased the N content of the straw from 7.0 to 18.6 g kg^{-1} DM. Urea supplementation raised the N content of the straw to 17.4 g kg^{-1} DM, a value which is close to that of urea-treated straw. The calculated proportions of urea-N retained in the USRS and UTRS were 113 (> 100%) and 50%, respectively. The changes in chemical composition due to urea treatment and urea spraying were slight increases in NDF, ADF and cellulose with a corresponding decrease in hemicellulose with no appreciable change in ADL and AIA. The AIA, which is mainly silica, formed 63% and 74% of the total ash with URS and USRS, respectively. Other chemical analysis showed little or no difference between URS, USRS and UTRS.

Degradability experiments

Degradability characteristics values from Eq. (1) are given in Table 3. As expected the *a*, *b* and rate constant *c* values were increased as a result of urea treatment of straw while USRS values were similar to URS except for the rate constant *c*.

Table 2
Chemical composition of untreated (URS), urea-sprayed (USRS), urea-treated rice straws (UTRS) *Brachiaria brizantha* hay and concentrates

	Roughages				Concentrates		
	URS	USRS	UTRS	*Brachiaria brizantha* hay (g kg^{-1} DM)	Fish meal	Rice bran	Cotton seed cake
OM	838	840	838	–	832	932	939
Ash	161	160	162	–	168	69	61
N	7.0	17.4	18.6	14	95	20	43
NDF	721	740	781	–	–		–
ADF	471	482	563	–	–		–
Cellulose	436	443	531	–	–	–	–
Hemicellulose	250	258	218	–	–	–	–
ADL	35	39	33	–	–	–	–
AIA	102	101	120	–	–	–	–

Table 4
LSMean growth performance and dry matter intake (DMI) by goats in the four treatment groups

	Treatment diets				SEM	Significance level
	USRS	USRS+FM	UTRS	UTRS+FM		
Feed intake (g kg^{-1} W$^{0.75}$)						
Straw DMI	23.1[a]	23.7[a]	59.3[b]	52.5[c]	±1.6	***
Fish meal DMI	–	2.7[a]	–	3.5[b]	±0.2	***
Rice bran DMI	22.6	22.6	30.0	27.9	±1.9	NS
Total DMI	45.8[a]	49.0[a]	89.4[b]	84.5[b]	±3.2	***
FM (g kg^{-1} DM straw)		115.0		62.0		
Crude protein (g kg^{-1})						
Total DMI	120	144	121	140		
Feed intake (g day^{-1})						
Straw DMI	153	156	426	401		
Rice bran DMI	144	149	248	216		
Fish meal DMI	–	19.5	–	25.2		
Total DMI	297	325	674	642		
Nitrogen	5.7	7.5	13.1	14.3		
Feed intake (% of live weight)						
Straw DMI	1.2	1.1	2.9	2.4		
Total DMI	2.3	2.3	4.3	3.8		
Liveweight (kg)						
Initial weight	12.3	11.8	13.7	12.6	±0.4	NS
Final weight	12.9[a]	13.8[b]	15.9[c]	17.0[d]	±0.1	***
Growth rate (g day^{-1})	3.3[a]	13.0[b]	36.9[c]	49.1[d]	±1.5	***
Feed efficiency						
FER[1]	91.4	24.8	18.6	13.1		
Weight gain per g FM DM[2] (g)		0.50		0.48		

[1]FER, feed efficiency ratio calculated as g total DMI g^{-1} liveweight gain day^{-1}.
[2]Difference in weight gain between fish meal supplemented and unsupplemented devided by the amount of fish meal in DM.

Feed efficiency

Urea-treatment of straw improved feed efficiency (g DMI g^{-1} live weight gain day^{-1}) from 91.4 to 18.6 compared with urea supplementation. Feed efficiency was greatly improved by FM supplementation in USRS diets from 91.4 to 24.8 and in UTRS diets from 18.6 to 13.1 (Table 4).

Discussion

Results obtained from this study for chemical composition, digestibility characteristics, intake and growth response of UTRS and USRS are generally

comparable with those reported by Ibrahim et al. (1989) for sheep; Silva et al. (1989) for sheep and cattle; and Tuen et al. (1991) for goats.

Chemical analysis of the fibre fraction of the rice straw (Table 2) did not show any significant change with urea treatment, and the NDF content tended to increase with urea treatment. This has also been reported for rice straw by Ibrahim et al. (1989) and Cann et al. (1991), but is different from the expected decrease in NDF content when straw of, for instance, barley is treated with NaOH (Rexen and Thomsen, 1976), or when wheat straw is treated with NH_3 or urea (Dias-da-Silva and Sundstøl, 1986). The reason for the different effect of treated rice straw compared with other straws may be because of the high silica and relative low lignin content of rice straw.

When urea was sprayed on the rice straw just before feeding all the nitrogen in the added urea could be found in the urea sprayed rice straw. On the other hand, when the rice straw was treated with urea and stored, there was a loss of nitrogen equivalent to 50% of the nitrogen in the added urea.

According to Ibrahim et al. (1989) the rice straw used in this study was of medium quality. In such situations one would expect a response with urea treatment. Dias-da-Silva and Sundstøl (1986) and Djajanegara and Doyle (1989) reported increased intake and digestibility in both urea treatment and urea supplementation owing to increased N per se and rate of digestion. Since it can be assumed that all of the degradation measurements were made under conditions which did not limit the fibrolytic activity the increase in the rate of digestion with USRS (Table 3) may imply that during the process of preparing the USRS samples for incubation, some NH_3 was released and this could have caused a similar effect as that of urea treatment of rice straw.

In this study, urea treatment, which presumably resulted in chemical change of the straw, was effective in increasing the intake, digestibility and utilization of rice straw by goats, when compared with urea supplementation. Hence a corresponding better growth performance in UTRS diets was seen compared with USRS diets. Similar responses with goats fed rice straw diets have been reported by Tuen et al. (1991). From the results, UTRS based diets with 65% UTRS could support the growth of goats, while USRS based diets could only maintain the body weight of the animals even when USRS was made only 50% of the total diet.

Urea-supplemented straw was consumed equally with or without FM supplement while FM supplementation reduced UTRS intake (Table 4). Although FM has been reported to enhance the intake of straws (Silva and Ørskov, 1988), the observed reduced intake of UTRS suggests that animals were able to consume enough UTRS to meet their daily energy requirements. Therefore, inclusion of the FM showed a substitutional effect with UTRS and an additive effect with USRS. The results are in agreement with Saadullah (1984) who observed little effect on DMI when FM was added to rice straw based diets.

The higher growth rate of the animals fed UTRS diets than of those fed USRS diets was also associated with a higher DMI of the straws. Increased

degradation of UTRS compared with USRS resulted in an increased intake with a corresponding increase in weight gain (Table 4).

Although FM supplementation did not improve DMI (Table 4) there was a marked improvement in the growth performance (Table 4) in both USRS and UTRS diets. The results are in agreement with earlier work (Saadullah, 1984; Silva et al., 1989; Chowdhury et al., 1991). Possible explanations for these responses vary widely. A review by ARC (1990) reported that FM provides rumen undegradable dietary protein (UDP) which increases the amount of total amino acids that is absorbed in the small intestines (AAT). Others (Silva and Ørskov, 1988; Silva et al., 1989) had similar views but further speculated that FM contained some nutrients important for optimum rumen function which were deficient in the basal diet. Chowdhury et al. (1991) reported that the response to FM supplementation of a straw diet was a result of the ability of the ruminants to utilize stored body fat as a source of energy to fuel protein deposition, resulting in marked body weight gains.

The FM used in this study had higher rumen degradability (Table 2), than that reported by other workers (e.g. Silva and Ørskov, 1988). The high degradability of the FM is probably because the FM was prepared from sun-dried fish and not from heat-treated or oil-extracted fish. Even if the FM used in this study had high rumen degradability it can be expected that about 35% of the FM protein escapes rumen fermentation (passage rate 6% h^{-1}).

The experiments conducted do not give an explanation for the mechanism of action for the positive result of FM supplementation, but show a significant effect of FM supplementation on weight gain, of the order of 0.5 g of weight gain g^{-1} of FM supplemented (Table 4).

Conclusions

The results from these experiments have clearly demonstrated that urea treatment is effective in improving the utilization of rice straw by increasing the rate and extent of degradation. Thus increasing straw intake to more than double and promoting the growth of dairy goats. These experiments also demonstrated that the response shown with UTRS was not caused by an increase in N per se but by chemical changes in the straw arising from the effect of NH_3 from urea.

The urea treatment effect on digestibility is not reflected in the chemical analyses of NDF, ADF or lignin of the rice straw. The N in urea added to rice straw just before feeding can all be recovered in the chemical analysis. Approximately 50% of the nitrogen added in urea to treat rice straw is recovered.

Supplementation of FM increased feed efficiency in the goats. Since URS was not fed to the animals, the experiments could not predict the effect of urea supplementation, which is the first thing to consider if the N content of the feed ration is low. The experiments showed that there is an effect of FM

supplementation, even if the N requirement of the rumen microorganisms are considered to be met, as was the case in these experiments. Therefore, although urea treatment and the FM supplementation were both very effective in improving rice straw utilization, both FM and urea supplementation could be of practical importance for situations where straw treatment is not convenient.

References

AOAC, 1990. Official Method of Analysis, 15th edn. Association of Official Agricultural Chemists, VA, pp. 69–88.

ARC, 1990. The Nutrient Requirement of Ruminant Livestock, 4th edn. CAB International, Wallingford, pp. 73–310.

Cann, I.K.O., Kobajashi, Y., Wakita, M. and Hoshino, S., 1991. Digestion properties of ammoniated rice straw in the rumen of lower tract of sheep. Anim. Feed Sci. Technol., 35: 55–68.

Chowdhury, S.A., Ørskov, E.R., Hovell, F.D. Deb and Mollison, G., 1991. Protein utilization during energy undernutrition in the ruminants. In: B.O. Eggum, S. Boisen, C. Børsting, A. Danflær and T. Hvelplund (Editors), Sixth International Symposium on Protein Metabolism and Nutrition. Denmark, 9–14 June 1991. EAAP, Publication No. 59, Tjele, Denmark, Vol. 2, pp. 154–160.

Dias-da Silva, A.A. and Sundstøl, F., 1986. Urea as a source of ammonia for improving the nutritive value of wheat straw. Anim. Feed. Sci. Technol., 14: 67–79.

Djajanegara, A. and Doyle, P.T., 1989. Urea supplementation compared with pretreatment. 1. Effect on intake, digestion and liveweight change by sheep fed a rice straw. Anim. Feed Sci. Technol., 27: 17–30.

Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analysis. United States Agric. A.R.S. Agriculture Handbook No. 379. Agricultural Research Services, USDA, WA, pp. 1–20.

Ibrahim, M.N.M., Tamminga, S. and Zemmelink, G., 1989. Effect of urea treatment on rumen degradation characteristics of rice straws. Anim Feed Sci. Technol., 24: 83–95

ICAR, 1985. Indian Council of Agricultural Research. Practical methods of straw treatment. In: J.B. Schiere and M.N.M. Ibrahim (Editors), Feeding of Urea-ammonia Treated Rice Straw. Pudoc, Wageningen, pp. 79.

Ørskov, E.R. and McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. J. Agric. Sci., 92: 499–503.

Owen, E. and Jayasuriya, M.C.N., 1989. Use of crop residues as animal feeds in developing countries. Res. Dev. Agric., 6 (3): 129–138.

Rexen, F. and Thomsen, K.V., 1976. The effect on digestibility of a new technique for alkali treatment of straw. Anim. Feed Sci. Technol., 1: 73–83.

Saadullah, M., 1984. Supplementing ammoniated rice straw for native cattle in Bangladesh. Ph.D. Thesis. The Royal Veterinary and Agric. University, Copenhagen, 140 pp.

SAS, 1988. Statistical Analysis System. SAS Users Guide. Version 6.03. SAS, Cary, NC, pp. 549–712.

Silva, A.T. and Ørskov, E.R., 1988. The effect of five different supplements on the degradation of straw in sheep given untreated barley straw. Anim. Feed Sci. Technol., 19: 289–298.

Silva, A.T., Greenhalgh, J.D.F. and Ørskov, E.R., 1989. Influence of ammonia treatment and supplementation on the intake, digestibility and weight gain of sheep and cattle on barley straw diets. Anim. Prod., 48: 99–108.

Snedecor, G.W. and Cochran, W.G., 1989. Statistical Method. 8th edn. pp. 149–397.

Tuen, A.A., Dahan, M.M., Young, B.A. and Vijchulata, P., 1991. Intake and digestion of urea-treated, urea-supplemented and untreated rice straw by goats. Anim. Feed Sci. Technol., 32: 333–340.

Wanapat, M., 1990. Nutritional aspects of ruminant production in Southeast Asia with special reference to Thailand. Funny Press, Bangkok, pp. 25–40.

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Degradation and utilization of grass cell walls by anaerobic fungi isolated from yak, llama and sheep

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Abstract

Anaerobic fungi were isolated from the rumen fluid of sheep and from the faeces of llama and yak. Based on morphology and growth characteristics, five isolates were identified as *Neocallimastix* species. One species, isolated from rumen fluid, showed properties characteristic for *Piromyces*. All the isolates were able to grow on cell walls isolated from perennial rye-grass. *Neocallimastix* species degraded the cell walls to a very high extent (89%) and were more efficient in cell wall degradation than *Piromyces* (64%). The major cell wall monosaccharides, glucose, xylose and arabinose were almost completely removed from the walls. Formate, acetate and hydrogen were the major end-products of fermentation, with lesser amounts of ethanol and lactate and only minor amounts of succinate being produced. All strains secreted cell wall degrading enzymes, including exoglucanase, endoglucanase, β-glucosidase, xylanase and β-xylosidase. Cellulolytic enzyme activities were highest in *Neocallimastix* species while xylanolytic enzyme activities were relatively high in the *Piromyces* culture.

Introduction

Ruminants are able to use plants with a high fibre content as feedstuffs, because of the breakdown of this material by a complex microbial population in the rumen. For many years, only specific groups of anaerobic bacteria and, perhaps to a lesser extent, protozoa were held responsible for this degradation. In the mid 1970s, however, the existence of anaerobic fungi as rumen inhabitants was reported (Orpin, 1975). These obligatory anaerobic fungi possessed chitin in their cell walls, they could be grown in a rumen simulating medium and were able to grow on fibrous plant materials (Orpin, 1975, 1977a; Bauchop, 1979).

Nowadays anaerobic fungi have been isolated from ruminants, ruminant-like animals and herbivorous animals possessing a hindgut fermentation (Orpin and Joblin, 1988; Bauchop, 1989; Milne et al., 1989; Teunissen et al.,

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