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Factors influencing the ammonia treatment of rice straw

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Small samples of ground rice straw (initial moisture content 7%) were treated at ambient temperatures with aqueous NH_3 at 2, 4, 6 and 8 % levels (on a dry matter basis). The final moisture content was 21%. Samples at each level of ammoniation were held for 7, 14, 21 and 28 days. The IVDMD of the samples, predicted from the pepsin-cellulose method, indicated a strong trend towards higher digestibility with increasing levels of NH_3 application, although the difference between 6% and 8% NH_3 was small. Treatment at ambient temperatures was completed in 7 days. In a second set of experiments, samples of straw were treated with 6% NH_3, such that the final moisture contents were 13% and 25%. These samples were stored at 30, 60 and 90°C, and for 6, 18, 72 and 168 hrs. IVDMD analyses indicated that increasing treatment time, temperature and moisture content of the straw, all had positive effects on the IVDMD.

Keywords: Rice straw; Ammonia treatment; Digestibility

Introduction

Rice straw, the principal cereal crop residue in the Caribbean, has considerable potential for increased usage in livestock production systems. This is particularly so for small island states where forage production may be limited by the availability of suitable land and water resources.

In its natural form, rice straw as a feed source is characterised by low levels of digestibility and protein content, as well as poor palatability. Through appropriate physical and/or chemical processing methods, the nutritive value of rice straw can be considerably improved. Physical methods of processing include straw chopping, grinding and steam treatment. Chemical methods, reviewed by Jackson (1978), include treatment with NaOH, NH_3 or urea.

NH_3 treatment of rice straw has considerable potential advantage over other chemical treatment processes, since it adds to the N content of the straw. However, both the rate and extent of the reaction between NH_3 and straw in terms of improvement in digestibility, are less than with NaOH. NH_3 treatment of straw may be accomplished through one of two methods.

- the polythene covered stack or box method
- the oven (FMA) method

In the first method, bales of straw are covered with a plastic sheet which is sealed to the ground by sand, and anhydrous NH_3 injected into the stack. The ammoniated stack is allowed to stand for weeks, under ambient farm conditions, before the plastic is removed,

excess NH_3 is liberated to the atmosphere and the straw fed to cattle. This process may be undertaken by placing the bales in a permanent structure such as a plywood box. In the oven (FMA) method, bales of straw are ammonia treated in a sealed, metal container for 24 hours at 90°C. The factors which affect the treatment of straw with NH_3 to improve the digestibility were noted by Sundstol et al (1978) as being ammonia level, treatment time and temperature, moisture content and initial quality and type of material. They noted little improvement in digestibility with increases in the NH_3 application level above 3-4 percent of dry matter. For ambient temperatures above 30°C, NH_3 treatments were less than 1 week. Waiss et al (1972) working specifically with rice straw, concluded that the optimum process conditions for ammoniation were 5 percent NH_3 for about 30 days at ambient temperature (22°C). Borhami and Sundstol (1982) reviewed the conditions necessary to obtain maximum digestibility of low quality roughages with NH_3 treatment, noting that the factors which influence the treatment process are cumulative.

This paper examines the NH_3 treatment process under ambient, tropical conditions. The effects of time, temperature and NH_3 level on the improvements in *in-vitro* dry matter digestibilities (IVDMD) of rice straw were studied. Attention was also given to the effect on the process of the reduction in moisture content of the straw which takes place after the harvest of the grain.

Materials and methods

Baled rice straw (Starbonnet) was air dried to 7 percent moisture content (wet basis), chopped to 25 mm in length by a forage chopper and ground in a hammer mill using a 3 mm screen. Ground straw samples, each of 64.5 g initial weight (60.0 g dry matter) were treated with aqueous ammonia (s.g 0.88, 33% NH_3).

In the first set of experiments, straw samples held in glass jars were treated with measured quantities of aqueous ammonia and additional water, such that 0, 2, 4, 6 and 8 percent NH_3 were applied (dry matter basis). Agitation assured effective mixing. The final moisture content of all treated samples was 18 percent. The samples were stored at 30°C in an incubator, and jars at each NH_3 level were opened after 1, 2, 3 and 4 weeks. On opening, the samples were thinly spread for 2 hours to eliminate excess NH_3. All samples were then dried at 60°C for 72 hours, prior to storage and subsequent analyses.

In the second series of experiments, samples (60 g, dry matter) of oven dried, ground rice straw were treated with aqueous ammonia to obtain a 6 percent NH_3 application (dry matter basis) and final moisture contents either 11 or 23 percent. Treated samples were stored at 30, 60 or 90°C in either an incubator or in forced convection ovens. Samples were removed after 6, 18, 72 and 168 hrs. They were aerated and dried as previously described, prior to storage and analyses.

A pepsin-cellulose solubility (ES) method, described by Goto and Minson (1977) which utilises the cellulolytic enzyme Onozuka SS was used as the basis for predicting the IVDMD of all the rice straw samples. Two procedural modifications were made to this technique. At the end of the pepsin incubation period, the supernatant was removed by filtration only, while at the end of the cellulose incubation period, the residue was removed by washing from the incubation tubes into a filtering crucible of known initial weight. The crucible containing the residue was then oven dried.

Results and Discussion

Predicting the *in-vitro* dry matter digestibilities (IVDMD): The IVDMD as determined by the rumen liquor method of Tilley and Terry (1963), is widely used to predict forage digestibility. The IVDMD of eight crop residue samples were determined by the Forage Laboratory, University of Guelph, and these results were correlated with the enzyme-solubility (ES) method used in this study. These results are shown in Table 1. The following quadratic model ($r^2 = 0.99$) was used to characterize the relationship between IVDMD and ES.

$$IVDMD = -6.025 + 1.770ES - 0.00894ES^2 \quad . \; . \; . \; . \quad (1)$$

A close relationship was shown between IVDMD and ES, over a wide range of dry matter digestibilities (Figure 1). It was therefore used to convert all the ES determinations to IVDMD data.

Level of NH_3 application and ambient processing time: The IVDMD of rice straw, ammoniated at ambient temperature (30^0C) at four levels of NH_3 application are shown in Table 2. The data represent the means of two observations.

The measured moisture content of the aqueous NH_3 treated rice straw averaged 21 percent. The IVDMD of untreated rice straw (control) averaged 41.2 percent. Using this IVDMD control value at zero time, asymptotic models of the form

$$y = a + be^{-kt} \quad . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

were fitted to the data, for the four levels of NH_3 application.

In this relationship; y = observed IVDMD; t is the treatment time in days; a, b and k are parameters representing the shape of the curve, where in particular, a is the estimated asymptotic value. The parameters fitted for the four levels were as follows.

NH_3 application level	a	b	k
2 %	51.3	-10.1	2.40
4 %	54.8	-13.7	0.27
6 %	58.0	-16.7	0.42
8 %	59.3	-18.1	0.38

These models are shown in Figure 2.

Analysis of variance of the data showed no significant effect due to time, indicating that the ammoniation process under ambient, tropical temperature was complete within 7 days of NH_3 application. This is illustrated in Figure 2, and is in general agreement with previous work on temperate straws (Sundstol et al 1978).

The effect of level of NH_3 application on the IVDMD of rice straw was highly significant ($p < 0.001$). Table 2 shows increasing IVDMD with higher NH_3 levels up to the highest application rate. These results differ somewhat from conclusions previously reported (Sundstol et al, 1978) with NH_3 application levels of higher than 4 percent, though in a later report, Sundstol et al (1979) noted some beneficial effects to increasing NH_3 level from 4.0 to 5.5 and 7.0 percent. The positive response obtained here at increased NH_3 application rates may be due to the initial lower quality of the rice straw and possibly to its higher moisture content.

The positive response of rice straw to NH_3 treatment is consistent with work previously reported by Kiangi and Kategile (1981). They found a maximum increase of up to 14 percent in IVDMD of straw treated with 5 percent NH_3 and noted that dramatic increases were obtained when straw was treated with up to 2.5 percent NH_3, while small but significant increases were obtained beyond this treatment level.

Table 1 Determinations of Dry Matter Digestibilities of crop residues by two methods: Pepsin-Cellulose Solubility (ES) and two-stage rumen liquor (IVDMD)

Sample	ES, (%)	IVDMD, (%)
Untreated rice hulls	5.2	3.2
3% NaOH-treated rice hulls	11.0	9.5
Untreated bagasse	14.5	19.3
3% NaOH-treated bagasse	25.5	35.8
5% NaOH-treated bagasse	35.3	48.0
7% NaOH-treated bagasse	52.7	59.8
Untreated cane tops	28.8	34.2
7% NaOH-treated cane tops	72.2	75.8

Table 2 The effect of level of NH_3 application on IVDMD (%) of rice straw

Time, (days)	Level of NH_3 Application, (% DM)				Means
	2	4	6	8	
7	51.6	51.4	58.5	58.3	55.0
14	48.8	55.7	54.4	56.9	54.0
21	53.7	54.5	57.9	61.9	57.0
28	51.2	54.0	60.5	58.8	56.1
Means[a)]	51.3	53.9	57.9	59.0	

a) SE = ± 0.85

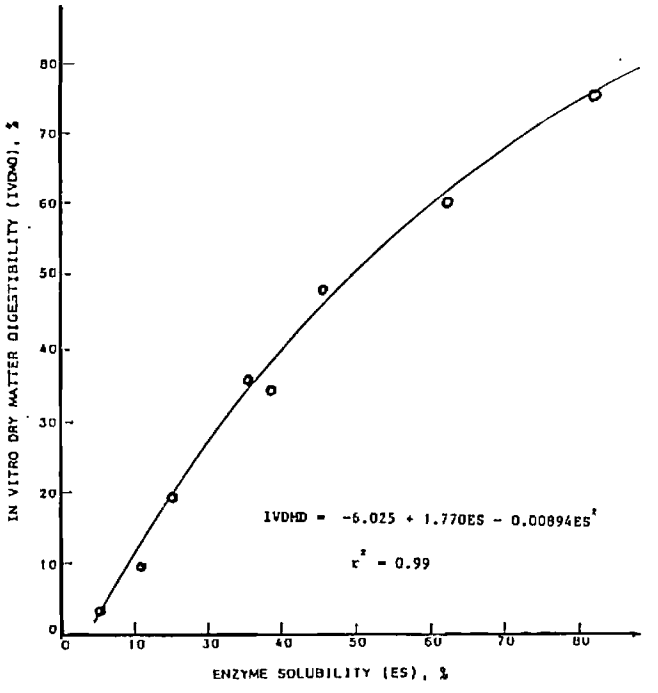

Figure 1 The relationship between *in vitro* dry matter digestibility (INDMD) and enzyme solubliity (ES)

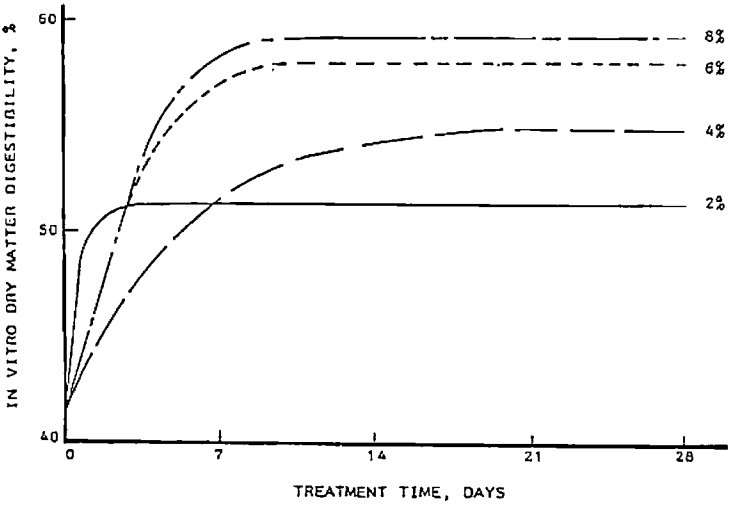

Figure 2 Regression curves for the IVDMD of NH_3 treated rice straw as a function of time at different NH_3 application levels

Process time/temperature/moisture content relationships

The IVDMDs of 6 percent NH_3 treated rice straw (at 13 and 25 percent moisture content as measured) are shown in Table 3, where the treatment temperatures were 30 (ambient), 60 and 90° C. Each value given in the body of the table is the mean of two observations.

Analysis of variance revealed that all the main effects and interactions were significant ($p < 0.001$ for all main effects; $p < 0.05$ for all interactions). IVDMD tended to increase with increasing treatment time, with the maximum rates of improvement occurring within the first 6 hr. of ammoniation.

Table 3 The effect of process time, temperature and moisture content on IVDMD of rice straw treated with 6% NH_3

Process Time (Hr)	IVDMD (%)					
	Moisture Content 13%			Moisture Content 25%		
	Temperature			Temperature		
	30°C	60°C	90°C	30°C	60°C	90°C
6	49.3	56.0	53.1	51.2	59.0	58.7
18	51.9	54.3	55.5	50.7	56.1	57.8
72	55.9	60.6	56.7	56.9	56.6	63.2
168	56.7	58.5	60.2	58.9	61.7	64.2

Overall Means Temperature (SE +_ 0.30) 30°C: 53.9, 60°C: 57.9, 90°C: 58.7
Time (SE + 0.35) 6 hr: 54.6, 18 hr: 54.4, 72 hr: 58.3 168 hr: 60.0
Moisture content (SE + 0.25) 13%: 55.7 25%: 57.9

Increasing the temperature generally resulted in higher IVDMD, with the values obtained at 60 and 90°C being markedly higher than those obtained at 30°C. As the process temperature increased, the reactions appeared to level off earlier. At 30°C (ambient temperature), a treatment time of 1 week appears necessary, confirming the results reported earlier. At 60 and 90°C, a treatment time of at least 3 days appears necessary to achieve the full benefits of ammoniation.

Increasing the moisture content of the rice straw from 13 to 25 percent generally raised the levels of IVDMD, with this being most apparent when the straw was processed at higher than ambient temperatures.

Conclusions

The treatment of rice straw with NH_3 is an effective method of improving the digestibility. Using the polythene stack method of treatment under ambient conditions (30^oC), an NH_3 application rate of 6 percent NH_3 (on a straw dry matter basis) appears suitable with the duration of treatment being seven days. The reduction in moisture content of rice straw after the harvesting of the grain will have little effect on the IVDMD of the straw, after ammoniation at ambient temperatures.

Treatment of rice straw with NH_3 at higher temperatures will increase both the rate and extent of the reaction in terms of IVDMD improvements, reducing treatment times from 7 to 3 days. Using the oven (FMA) process, a 24 hour treatment appears inadequate to produce maximum benefits. With high temperature ammoniation, straw at a high moisture content gives greater increases in IVDMD.

While this study did not investigate the effect of NH_3 treatment on the crude protein (CP) content of rice straw, results obtained indicate that at 6 percent NH_3 application level, the CP content of the straw increased from 4.5 to 9.8 percent after 1 week at ambient temperatures. Such results are consistent with those reported previously.

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