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Response of Several Legume and Cereal Roughages to Ammonia Treatment

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THe response of wheat and rice straws, maize stover, fababean, soybean and clover straws and rice hulls to ammonia treatment was studied in this investigation. The experimental design was a 7x 3x 3 factorial with the seven roughages, 3 ammonia levels: 0 (control), 25 and 35 g NH_3/kg. roughage DM and 3 moisture levels: natural (13.5%, on average), 20 and 25%. Ammoniation was carried out with 200 g DM in sealed plastic bags for one month at ambient temperature Protein content was higher in legume than cereal roughages. Ammoniation with 25 and 35 g NH_3/kg DM increased protein content by 94 and 113% over that of control. In vitro dry matter digestibility (IVDMD) was increased by 6.2 and 8.1 percentage units over control with 25 and 35 g NH_3 levels, respectively. Legume straws had higher initial IVDMD and responded less to ammonia treatment than cereal straws. Raising moisture content had a positive effect on protein content and IVDMD, although this effect was limited in its magnitude.

Ammonia treatment decreased neutral detergent fiber (NDF) and hemicellulose but had no effect on acid detergent fiber (ADF) or lignin contents. Legume straws were characterized by lower NDF and hemicellulose but higher lignin than cereal straws. Rice hulls had the lowest protein, IVDMD, highest NDF and cellulose. It is concluded that ammonia treatment of legume straws has limited influence to upgrade them, however, other oxidative methods might be more effective. Ammoniation at natural moisture content is sufficient to attain most of the improvement achieved with higher moisture contents.

Keywords: Legume, cereal roughages, Amoniatreatment, chemical analysis and in vitro digestibility.

Ammonia treatment of poor quality roughages has proved to be a valuable process for upgrading the nutritive value. Wide spread application of the method was initiated after the success of the "On farm method" (Sundstol *et al*.., 1978).

Numerous studies were conducted to define the optimal conditions of ammoniation process, including dosage and form of ammonia, moisture content, temperature, duration of the treatment and the materials to be treated. Although ammonia treatment included variety of materials, much concern was directed toward cereal by-products including straws of barley (Waagepetersen and Vestergaard Thomson, 1977; Kernan *et al*., 1979 and Horton, 1981), wheat (Solaiman *et al*., 1979; kiangi *et al*., 1981 and Horton, 1981), rice (Waiss *et al*., 1972; Tohrai *et al*., 1978 and El-Ayouty *et al*., 1988) maize stover (Oji *et al*, 1977 and El-Ayouty *et al*., 1988) , oat, (Kernan *et al*., 1979 and Horton, 1981) and rice hulls (Fahmy *et al*., 1968 and Tohrai *et al*., 1978). Less attention was paid to legume straws (Waiss *et al*., 1972 and Kernan *et al*., 1981). The response of cereal straws in general is greater than legume straws (Waiss *et al*., 1972).

Levels of ammonia as low as 2.5% is sufficient to attain most of the improvement, a further rise of ammonia level resulted in a small additive effect (Sundstol *et al*., 1978). With very dry materials (3.3% moisture content) ammonia treatment was without effect on the in vitro digestibility (Sundstol *et al*., 1979).

Borhami and Sundstol (1982) found a continuous increase of in vitro dry matter digestibility (IVDMD) as the moisture content of oat straw was elevated from 2.5 to 10%. solaiman *et al*. ,(1979) observed similar trend with moisture contents ranging from 10 to 50%. However, high moisture contents may hinder better distribution of ammonia and create problems related to transportation and storage.

El-Ayouty *et al*. , (1988) treated maize stover and rice straw with either 3 or 5% anhydrous ammonia. Although 5% NH_3 was superior to 3% in respect to crude protein content and IVDMD, 3% NH_3 attained most of the improvement achieved by 5% NH_3 level. Raising the moisture content of rice straw from 5 to 15% and that of maize stover from 10 to 20% had a pronounced effect in the ammoniation process.

The objective of the present study was to test the response of some cereal by-products in addition to legume straws to ammonia treatment under moderate levels of both ammonia dosage and moisture content.

Material and Methods

The following materials were used in this study

1- Wheat straw, *Triticum aestivum* L. chopped to 2-4 cm, moisture content 10%.
2- Rice straw, *Oryza sativa*, chopped to 3-6 cm, moisture content 16%.
3- Maize stover, Zea mays, chopped to 2-4 cm, moisture content 15.2%.
4- Fababean straw, Vicia faba L., chopped to 2-4 cm, moisture content 13.8%.
5 - Soybean straw, Glycine max, chopped to 2-4 cm, moisture content 16%.
6- Clover straw, Trifolium alexandrinum, chopped to 2-4 cm, moisture content 13.5%.
7- Rice hulls, Oryza sativa, moisture content 10.2%.

The study was conducted as a factorial experiment involving the 7 roughages, 3 anhydrous ammonia dosages (25 and 35 g NH_3/kg DM), and 3 moisture contents (natural, 20 and 25%).

After adjusting the moisture content to the required level, an equivalent of 200 g DM was put in a plastic bag, sealed and infused with the required dosage of ammonia (weight basis) and stored at room temperature (about 20°C) for one month. treatment combinations were assigned to duplicate samples.

The bags were opened, the treated material dried over night at 50-60°C, left to equilibrate with atmospheric moisture and then, ground through 1-mm screen for analysis.

Analyses

Crude protein (Kjeldahl process), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were carried out on duplicate samples according to the method of Goering and Van Soest (1970). Cellulose was calculated as ADF-ADL, and hemicellulose as NDF-ADF.

In vitro dry matter digestibility (IVDMD) was performed by the method of (Alexander and McGowan, 1966) utilizing rumen fluid from two rumen-fistulated bulls fed on clover hay.

The data were statistically analyzed as a factorial experiment 7x3x3. The differences among means were tested with the Duncan's new multiple range test (Steel and Torrie, 1980).

Results and Discussion

The effects of ammonia level, moisture content and roughage type on chemical composition and IVDMD are presented in Table 1.

TABLE 1. Effects of ammonia and moisture levels and roughage type on crude protein content, in vitro dry matter digestibility (IVDMD) and cell wall constituents.

	Protein	IVDMD	NDF	ADF	ADL	Cellulose	Hemi-Cellulose	Ash
Ammonia level								
g/kg DM (A)	5.5^{a}	37.4^{a}	73.4^{a}	55.3	10.1^{ab}	44.8	18.5^{a}	13.1
250.0	10.7^{b}	43.6^{b}	71.0^{b}	55.3	10.4^{a}	45.0	15.3^{b}	13.1
30	11.7^{c}	45.5^{c}	70.9^{b}	55.6	9.8^{b}	45.3	15.4^{b}	13.0
Moisture Content (M)								
Natural	9.0^{a}	41.0^{a}	71.8	55.1	9.9	44.8	16.5^{a}	13.4
20%	9.3^{ab}	42.9^{b}	71.3	10.4	10.4	44.9	15.3^{b}	13.0
25%	9.6^{b}	42.6^{b}	72.2	55.9	10.0	45.5	15.6^{ab}	12.9
S.E for A or M	0.12	0.40	0.39	0.28	0.18	0.31	0.42	0.16
Roughages (R)								
Wheat straw	6.8^{a}	46.1^{a}	76.9^{a}	54.0^{a}	7.2^{a}	54.8^{a}	22.5^{a}	12.4^{a}
Rice straw	7.8^{b}	42.2^{b}	74.1^{b}	54.0^{a}	4.9	49.1^{b}	20.2^{b}	16.2^{b}
Maize stover	7.5^{b}	41.3^{b}	79.3^{c}	51.6^{b}	8.0^{b}	43.8^{c}	27.8^{b}	8.1^{c}
Fababean straw	15.8^{c}	54.5^{c}	58.3^{d}	48.3^{c}	10.7^{c}	37.6^{d}	9.7^{c}	9.8^{d}
Soybean straw	10.7^{d}	54.2^{c}	62.7^{e}	52.8^{ab}	10.4^{c}	41.4^{e}	10.3^{c}	11.0^{e}
Clover straw	11.2^{d}	47.6^{a}	63.8^{e}	53.4^{a}	12.2^{d}	41.2^{e}	10.3^{c}	15.6^{b}
Rice hulls	5.2f	9.3d	87.8^{f}	73.7^{d}	7.0^{a}	56.6^{f}	14.0^{d}	18.4^{f}
S.E. for (R)	0.18	0.62	0.61	0.43	0.27	0.48	0.64	0.25
Interactions								
A x M	N.S	*	*	N.S	*	N.S	N.S	N.S
A x R	*	*	*	*	*	*	*	N.S
M x R	N.S	N.S	N.S	N.S	N.S	*	N.S	*
A x M x R	N.S	*	N.S	N.S	*	N.S	N.S	N.S

a,b,c,d,e,f means within each exprimental factor bearing small letters differ at P< 0.05
N.S. Not significant, * Significant at P< 0.05

Protein content

On average ammoniation with 25 and 35 g NH_3/kg DM increased protein content from 5.5% (for O NH_3 level) to 10.7 and 11.7%, respectively; this improvement corresponded to 94 and 113% increase over control. Ammonia level of 25 g/kg DM attained most of the improvement reached by the 35 g NH_3 level, although the difference between the two levels was significant ($P < 0.05$).

Legume straws had higher protein contents than cereal straws with fababean straw showing the highest value (15.8%) and rice straw exhibiting the lowest value 5.2%.

Raising moisture content from the natural level (13.5%, on average) to 20 and 25% elevated the protein content from 9.0 to only 9.3 and 9.6%, respectively. The only significant difference was between the highest and lowest level of moisture.

The interaction of ammonia level with roughage type was significant ($P< 0.05$). The responese in CP different roughages to ammoniation is presented in Table 2. The protein contents of untreated cereal straws were lower than these of the untreated legumes. Absolute increases in CP (average of 25 and 35 g NH_3/kg DM) were 5.3; 4.4; 4.3; 10.3; 6.0; 4.4 and 3.7 percentage units for wheat, rice straw, maize stover, fababean, soybean and clover straws and rice hulls, respectively the increase in protein content of ammoniated roughages is well authenticated (Horton and Steacy, 1979; Sundstol *et al.*, 1979; Kernan *et al.*, 1981; Kiangi *et al.*, 1981 and Alibes *et al.* 1984).

TABLE 2. Effect of ammonia level on crude protein content (% of DM) of different roughages.

Roughage type	Ammonia level g/kg DM		
	0	25	35
Wheat straw	3.3[a]	8.0[b]	9.1[c]
Rice straw	4.9[a]	8.0[b]	9.6[b]
Maize stover	4.9[a]	9.0[b]	9.3[b]
Fababean straw	8.9[a]	18.7[b]	19.7[c]
Soybean straw	6.0[a]	12.9[b]	13.2[b]
Clover straw	8.2[a]	11.6[b]	13.7[c]
Rice hulls	2.7[a]	5.8[b]	7.1[c]

1- a,c,b Means in the same row bearing different letters differ at $P < 0.05$.

In vitro dry matter digestibility (IVDMD)

Ammoniation with 25 and 35 g NH_3/kg DM increased IVDMD,on average by 6.2 and 8.1 percentage units over the controls. Raising moisture content had a significant ($P< 0.05$) effect on IVDMD, although this effect was limited in its magnitude, since IVDMD was increased by only 1.9 percentage units.

Kiangi *et al.* (1981) found that increasing moisture content from 20 to 40% raised IVDMD by only 1 percentage unit and Waiss *et al.* (1972) pointed that the optimum moisture content for ammoniation is 30%, although better results in IVDMD were obtained with levels lower than 30% moisture content. Sundstol (1984) stated that the optimum moisture content, for practical purposes, probably lies between 15 and 20%. From the results reported herein, it seems that the average level of natural moisture content (13.5%) is quite suitable for ammonia treatment.

The responses in IVDMD of different roughages to ammonia treatment are given in Table 3, In general, the untreated legume straws had higher IVDMD than the untreated cereal straws with fababean and soybean straws showing the highest values. The IVDM of the untreated rice hulls was very low, making it unsuitable as a feedstuff. The increase in IVDMD due to ammoniation (average of 25 and 35 g NH_3/kg DM) were 15.0, 14.8, 7.8, 3.1, 1.2, 5.6 and 5 percentage units over control for wheat and rice straws, maize stover, fababean, soybean and clover straws and rice hulls, respectively. It is obvious that the improvement in cereal straws was much higher than those in legume straws. The response of maize stover was much lower than that of wheat and rice straws.The magnitude of response in IVDMD of maize stover is similar to the results of Oji *et al.* (1977) and Kiagi *et al.* (1981) but lower than those of Albies *et al.* (1984) and El-Ayouty *et al.* (1988). The magnitude of response in rice straw is similar to other results (Kiagi *et al.*, 1981 and El-Ayouty *et al*, 1988) and that of fababean straw is similar to that obtained by Kernan *et al.* (1981). Ammoniation did, however, not improve the IVDMD of soybean.

TABLE 3. Effect of ammonia level on in vitro dry matter digestibility (IVDMD) of different roughages (%).

Roughage type	Ammonia level g/kg DM		
	0	25	35
Wheat straw	36.2^a	49.9^b	52.2^c
Rice straw	31.9^a	47.4^b	47.1^b
Maize stover	36.1^a	42.1^b	45.6^c
Fababean straw	52.4^a	55.6^b	55.4^b
Soybean straw	55.1	52.9^b	54.7
Clover straw	44.2^a	47.0^b	51.7^c
Rice hulls	6.0^a	10.4^b	11.6^b

1- a,b,c Means in the same row bearing different letters differ at $P < 0.05$.

The lower response of legume than cereal straws to ammonia treatment reported herein is in agreement with Waiss *et al.* (1972) and Kernan *et al.* (1981). The legume straws here had higher initial digestibility than cereal straws thus it is expected that the improvement in legume straws to be lower than cereal straws; as the effectiveness of ammonia treatment is related inversely to the initial nutritive value of the treated material as reviewed by Sundstol and Coxworth, (1984). Nevertheless, other factors may contribute to differences between legume and cereal straws. Oji (1979) drew attention to the higher content of lignin in legumes than in grasses, and that the nature of the chemical bonds differ. The lignin-polysaccharide bonds in cereal straws are of ester type (Hartely, 1972) but those in legume straws are of glycosidic type (Harkin, 1973) which may be more resistant to cleavage by alkaline or ammonolysis than the ester bonds in cereal straws.

Cell wall fractions

Ammonia treatment decreased both NDF and hemicellulose contents of roughages (Table 1). Raising moisture content had no effect on NDF and a little effect on hemicellulose. Ammoniation, however, had different effects on different straws (Table 4). Wheat and rice straws and maize stover showed decreases in NDF due to ammoniation, with no difference between the ammonia levels. On the other side, fababean straw showed no change whereas NDF in soybean straw was slightly increased after ammoniation. Clover straw NDF decreased only with the 35g NH_3 level. NDF in rice hulls showed a small decrease due to ammoniation. Untreated cereal straws were characterized by higher NDF contents than the untreated legume straws. The decrease in NDF of ammoniated roughages had been observed by others (Solaiman *et al.*, 1979; Itoh *et al.*, 1979; Horton 1981; Brown 1988 and El-Ayouty *et al.*, (1988).

The hemicellulose contents of the untreated cereal straws were twice higher, or even more, than the levels occurred in legume straws. Among the untreated cereal straws wheat straw and maize stover had higher hemicellulose contents than rice straw. Rice hulls had lower hemicellulose than other cereal straws but slightly higher than legume straws. In general, although ammonia treatment decreased hemicellulose content, different roughages responded variabely. The largest decrease was observed in wheat straw. Similar decreases were noticed in ammoniated rice straw and maize stover. Fababean and soybean straws showed relatively, in comparison with the initial values, more decrease than cereal straws. Clover straw and rice hulls showed a little response to ammonia treatment.

Neither ADF nor cellulose was significantly affected by ammoniation or increasing moisture content. Notwithstanding this, small decreases in ADF occurred in ammoniated maize stover, clover straw and rice hulls. On the other side, ADF and cellulose was noticed to increase in fababean and soybean straws after ammonia treatment. El-Ayouty *et al.* (1988) and Brown (1988) found that ammonia treatment did

TABLE 4. Effect of ammonia treatment on the cell wall fractions of different roughages.

	NDF	ADF	ADL	Cellulose	hemi-cellulose
Wheat straw					
0 NH_3	81.1[a]	74.3[a]	7.5[a]	46.4	27.5[a]
25 NH_3	73.6[b]	52.9[b]	7.3	45.2	20.4[b]
35 NH_3	74.2	54.6[a]	6.7	45.9	19.6[b]
Rice straw					
0NH_3	76.2[a]	53.9	5.3	48.5	22.3[a]
25 NH_3	73.1[b]	53.9	4.7	49.2	19.1[b]
35 NH_3	73.1[b]	54.1	4.7	49.4	19.2[b]
Maize stover					
0NH_3	81.3[a]	52.4[a]	7.10[a]	44.5[a]	29.6[a]
25 NH_3	78.1[b]	51.5[ab]	9.60[b]	42.0[b]	26.5[b]
35 NH_3	78.5[b]	50.9[b]	6.5[a]	44.9[a]	27.3[b]
Fababean straw					
0NH_3	58.7	46.5[a]	10.0[a]	36.4[a]	12.3[a]
25 NH_3	57.9	49.5[b]	11.4[b]	38.1[b]	8.3[b]
35 NH_3	58.2	48.8[b]	10.8[ab]	38.2[b]	8.5[b]
Soybean straw					
0NH_3	61.8[a]	49.8[a]	10.3[a]	38.7[a]	12.9[a]
25 NH_3	63.6[a]	53.1[b]	10.3[a]	42.8[b]	9.1[b]
35 NH_3	62.6[ab]	55.4[c]	12.9[b]	42.8[b]	9.0[b]
Clover straw					
0NH_3	65.2[a]	54.7[a]	11.5[a]	41.3	10.5[ab]
25 NH_3	64.4[a]	53.1[b]	12.9[b]	41.4	11.3[a]
35 NH_3	61.8[b]	52.5[b]	11.6[a]	40.8	9.3[b]
Rice hulls					
0NH_3	89.1[a]	75.4[a]	17.1	57.1[a]	14.3[ab]
25 NH_3	86.5[b]	73.0[b]	16.5	56.6[ab]	12.7[a]
35 NH_3	87.9[ab]	72.7[b]	17.1	55.2[b]	15.2
S.E	0.6	0.4	0.3	0.5	0.6

a, b, c Means in the same column within each roughage type bearing different letters differ at $P< 0.05$.

not affect ADF in cereal straws, whereas Kernan *et al.*(1981) with fababean straw showed that ammonia treatment increased ADF fraction from 43.6 to 48.4%. The highest ADF and cellulose contents were found in rice hulls whereas fababean straw had the lowest values. Cellulose contents were higher in cereal than legume straws.

Acid dtergent lignin (ADL) was slightly affected by ammoniation, although the difference between the ammonia levels was significant (P> 0.05). Raising moisture contents had no effect on ADL. legume straws had higher ADL Contents than cereal straws. However the highest ADL Levels were observed in rice hulls.

The ratio of lignin to cellulose is higher whereas that of hemicellulose to cellulose is lower in legume than in cereal straws. This is in agreement with Van Soest (1982).

Ash content was not influenced by either ammoniation or increasing moisture content.

It is concluded that ammonia treatment is effective in upgrading cereal straws but has limited influence on legume straws; other oxidative methods might be more effective. Ammoniation at natural moisture contents is sufficient to attain most of the improvement.

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أستجابة بعض المواد الخشنة البقولية والنجيلية للمعاملة بالامونيا

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درست فى هذا البحث استجابة عدة مواد للمعاملة بالامونيا ، تشمل هذه المواد تبن القمح وقش الارز وحطب الاذرة وأتبان الفول البلدى وفول الصويا والبرسيم وكذلك سرسة الارز.

وقد أجريت التجربة على هيئة تصميم عاملى ٧ × ٣× ٣ يشمل المواد السبعة المعاملة ، ثلاثة مستويات أمونيا : صفر (المقارنة) و ٢٥ و٣٥ جم أمونيا / كجم مادة جافة وثلاثة مستويات رطوبة طبيعية (٥ر١٣٪ فى المتوسط) و ٧٠٪ و ٢٥٪. وقد أجريت المعاملة بالامونيا الغازية لما يكافئ ٢٠٠ جم مادة جافة فى أكياس بلاستيك لمدة شهر واحد على درجة حرارة الغرفة.

وأشارت النتائج الى أن محتوى البروتين كان مرتفعا فى المواد الغشنة البقولية عن نظيرتها النجيلية. وقد أدت المعاملة ب ٢٥ و ٣٥ جم أمونيا الى تحسن محتوى البروتين بنسبة ٩٤ و ١١٣٪ عن عينات المقارنة

أما معاملات الهضم المعملية IVDMD فقد تحسنت بمقدار ٦ر٢ و ٨ر١ وحدات عن المواد غير المعاملة وكانت معاملات الهضم المعملية للبقوليات غير المعاملة مرتفعة عن نظيرتها للنجيليات وأن استجابة هذه البقوليات للمعاملة بالامونيا كانت أقل من النجيليات.

وقد أدى رفع نسبة الرطوبة الى أثر إيجابى على نسبة البروتين ومعاملات الهضم المعملية بالرغم من أن هذا الأثر كان محدودا في قيمته.

وقد أدت المعاملة بالامونيا الى تقليل بعض مكونات جدار الخلية مثل NDF والهيميسليلوز ولم يكن لها تاثير على ADF واللجنين. وقد تميزت أتبان البقوليات بانخفاض NDF والهيميسليلوز وارتفاع اللجنين من أتبان النجليات. وقد تميزت سرسة الارز باحتوائها على أقل نسبة بروتين وأعلى نسبة NDF وسليلوز.

وقد استنتج أن المعاملة بالامونيا للمواد الخشنة بدون رفع نسبة الرطوبة يؤدى الى التحسين المنشود فى القيمة الغذائية.