PRESERVATION AND QUALITY IMPROVEMENT OF SEMI-DRIED ROUGHAGES BY AMMONIA TREATMENT

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ABSTRACT

Hay has several advantages over silages in terms of the preservation, transportation and handling of the products. However, there are various problems in hay-making in the monsoon zone including Japan, since the weather conditions during the harvesting period of hay crop are unfavorable and characterized by rain and a high humidity level especially, at the time of the lst cutting which is associated with the highest yield.

Under these conditions, almost all of the field-cured hay would be too wet to be baled for storage. When hay is baled at a moisture level exceeding 20-25%, mold growth is promoted, generating heat that can reduce significantly the feeding value. On the other hand, hay baled at too low a moisture content is subject to mechanical shattering of leaves and slender stems, which results in a high loss of dry matter and nutrients.

It has been recongnized that anhydrous ammonia (NH_3) was rapidly absorbed by moist tissues and was lethal to mold. Furthermore, this substance has shown a positive effect in improving the nutritive value of low quality roughages.

Therefore, experiments were carried out to evaluate the preservation of roughage hay baled at 25 to 40% moisture level by the application of anhydrous ammonia. Ammoniation was carried out in the field in applying the stack method. The bales with semi-dried roughage hay were stacked in a sunny place, and covered with a transparent plastic sheet. The materials were sealed and injected with anhydrous ammonia at 3 to 4% (W/W) of dry matter, and then left for above one week before use as feed.

Ammonia treatment prevented the occurrence of molding and heating of semi-dried stored hay, and improved significantly hay quality by increasing the total nitrogen content, cell wall digestibility and feeding value. In addition, ammonia treatment destroyed weed seeds and *Fasciola* eggs. Ammonia treatment does not require an elaborate processing equipment to incorporate and to distribute the reagents evenly unlike other alkali treatments. Therefore, it is anticipated that the present method will be readily adopted by many farmers.

In Japan, most of the stored roughages consist of hay and silage. Hay is somewhat more suitable since it is more readily preserved, transported and handled than silage. However the relatively rainy, highly humid and hot weather at the harvesting season of roughages in a monsoon area such as Japan makes it difficult to prepare and store a large amount of excellent hay by field curing at a low cost. This is particularly the case for the first cutting grasses which are associated with the highest yield.

Due to the rainy and highly humid weather, most of the field-cured hay is baled and stored in an insufficiently dried form to avoid rain damage which might result in the loss in the nutritive value of dried hay, which in turn lowers its feeding quality. In addition, the first cutting hay becomes frequently wet and moldy during storage in summer, even if thoroughly dried.

Hay containing more than 20 to 22% of moisture tends to become moldy and hot during the storage resulting in the loss of its nutritive and feeding values. On the other hand, highly nutritious leaves and slender stems in field-cured forage may be mechanically shattered, which also leads to the decrease in their nutritive value.

Under these circumstances, it is desirable to preserve roughages in a semi-dried form to avoid rain damage by shortening the field-curing period as well as to prevent the decrease in

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nutritive value.

Ammoniation has been considered as the best method for achieving this objective, since gaseous ammonia (NH_3) is highly volatile, expandable and soluble in water in plant tissues. It further exhibits a fungicidal and bactericidal activity. In addition, ammonia appears to improve the feeding quality of roughages, which is particularly beneficial when the material to be treated is in a semi-dried form and contains approximately 30% of moisture. We have studied the process of ammoniation and obtained the following results.

Procedure for ammoniation

Ammoniation should be carried out on a sunny day outdoors in adopting the stack method to avoid accidents and to reduce labor and cost.

1 Stack preparation

An old plastic sheet was spread over a well drained flat surface. Baled hay materials containing 25 to 40%of moisture were heaped up on hurdles 10 to 20 cm in height placed on the sheet. These hurdles were used to allow the ammonia gas to readily spread at the bottom of the stack.

The stack was covered with a transparent plastic sheet at the borders of which soil or sand was placed to seal the stack.

2 Addition of ammonia

Gaseous ammonia was applied to the center of the bottom part of the stack through a rubber tube from a cylinder containing liquid anhydrous ammonia (standard marketing and packing by 50 kg in Japan). The ammonia gas was injected slowly enough for the 50 kg of the liquid anhydrous gas in the cylinder to evaporate and the injection to the stack required at least more than 24 h.

After adding the ammonia, the stack was allowed to stand as such (i.e. in the sealed form) for at least one week to complete the ammonia reaction.

Subsequently, the stack was opened and allowed to be aerated so as to remove the excess of free ammonia prior to utilization.

Effects of ammoniation

1 Ammonia level

One of the effects of ammoniation was the improvement of the preservability by sterilization. Fig. 1 shows this effect in relation to the moisture level of the hay material and the level of ammonia added. Preservability increased with the decrease in the moisture level and the increase in the ammonia level, even though hay containing 50%of moisture could be preserved successfully over two weeks by adding 3% of ammonia on a dry basis.

Another effect of ammoniation was manifested by the improvement of the feeding value such as the increase in nitrogen content and digestibility and improved voluntary intake. Fig. 2 shows the effect of the level of ammonia added on the total nitrogen content and Enzymatic Organic Matter Digestibility (EOMD; solubility of organic matter by pepsine and cellulase).

The total nitrogen content and the EOMD increased with the increase of the level of ammonia added. However EOMD increased more slowly than the total nitrogen content and increased only slightly when the level of ammonia added exceeded 4% based on the raw materials in hays containing 42% and 30%of moisture. Therefore it may be desirable from the economic point of view to add ammonia at a level of less than 4% on a dry basis since ammonia is relatively expensive in Japan.

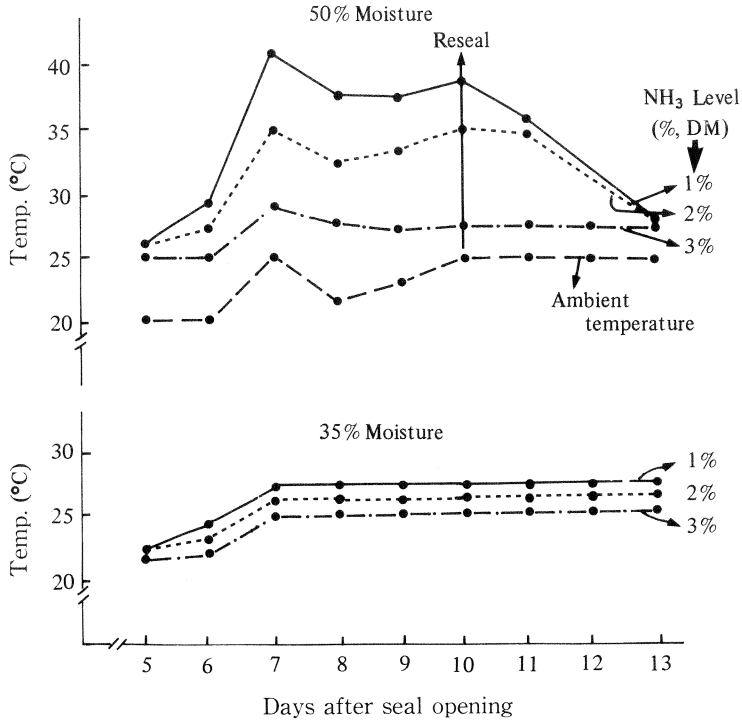

Fig. 1 Effect of NH_3-level and moisture level on the temperature of NH_3-treated hay bale during storage after opening the seal.

2 Time of treatment

Fig. 3 shows the relationships between the duration of storage in the sealed form and total-N content and EOMD. Grass hay was treated at a relatively high temperature (25°C) while rice straw was treated at a relatively low temperature (4° to 10°C), and the ammonia reaction with the materials was completed within 10 to 14 days. Even if the reaction is completed, in practice, it is desirable to continue to keep closed conditions, because the ammonia reaction is not toxic and enhances the preservability of the materials.

Benefits from ammoniation

1 Fungicidal effect

Molding and heating usually tend to spoil hay baled at a moisture level of more than 20 to 22%. However ammoniation with 2% of ammonia made it possible to store hay containing a moisture level of less than 40 to 45% without spoilage. It was found necessary to add ammonia at a concentration of more than 2% on a wet basis when the moisture level exceeded 45 to 50%.

2 Nitrogen enrichment

Approximately 30% of the ammonia added mainly forms a hemicellulose bond with organic matter in the materials resulting in the increase of the contents of total nitrogen and DCP.

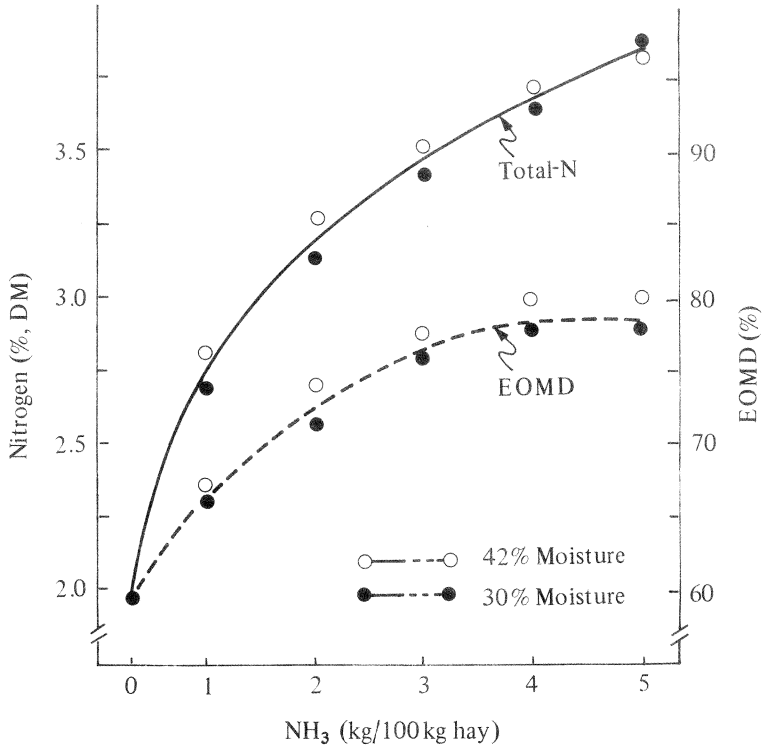

Fig. 2 Effect of NH_3 level on total-N content and EOMD of semi-dried hay treated with NH3.
EOMD: Enzymatic Organic Matter Digestibility.

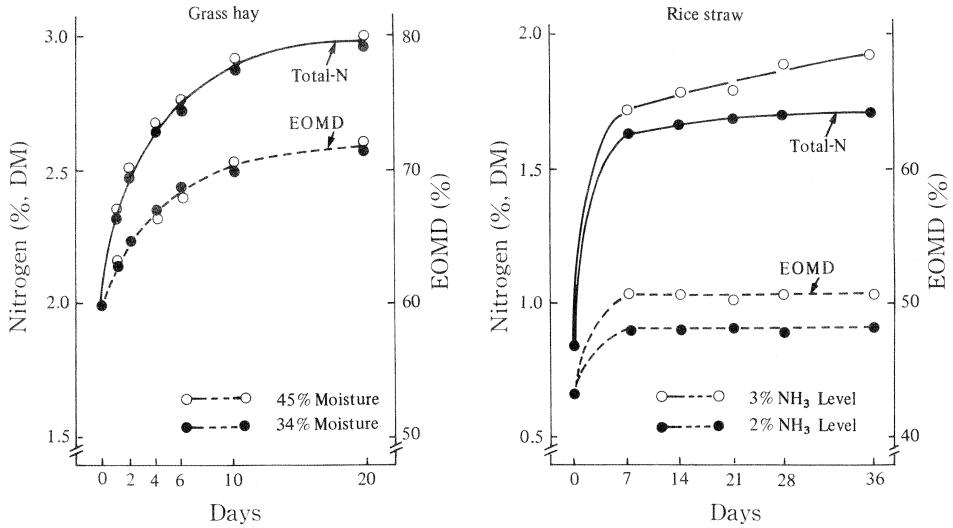

Fig. 3 Effect of time interval after treatment on total-N content and EOMD of semi-dried roughages treated with NH_3.

3 Digestibility

Ammoniation reduces the content of hemicellulose in the fibers by converting it into digestible matter partially. Ammoniation further enhances the digestibility of residual hemicellulose resulting in the improvement of the digestibility of organic matter in the treated hay along with the improvement in the nutritive value (i.e. TDN and DCP).

4 Intake of ammoniated materials

Ammoniation softens the roughage tissues and improves their digestibility and nutritive value, hence their intake. Consequently, ammoniation raises the nutritive intake.

5 Other advantages

It was further observed that ammoniation destroys weed seed and *Fasciola* eggs.

Compared to other alkali treatments such as NaOH or $Ca(OH)_2$, the ammonia treatment requires no elaborate processing equipment for the incorporation and distribution of the reagents and can be carried out safely outdoor at any scale.

Cost and applicability

It is important to reduce the cost of NH_3 which accounts for more than 90% of the total cost of the operation. It is also necessary to adjust the moisture content of the materials to 25 to 35%.

Ammoniation makes it possible to store for a long time a material which is liable to mold and heat due to its relatively high moisture content. Ammoniation also contributes to the improvement of the feeding value of the material. Therefore it is reasonable to subject to ammoniation insufficiently dried roughage hay of low quality such as late cutting grass, grass containing weeds, rice and/or barley straws harvested with a combine and other crop

Table 1 Effect of ammoniation on the qualitative improvement of orchard grass hay harvested at the later stage and/or including weed

Item	Ist cutting orchard grass				Pre-blooming stage including weed	
	Heading stage		Pre-blooming stage			
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Chemical composition (%, DM)						
Crude protein	11.8	17.4	10.5	15.6	11.1	16.9
N D F	65.5	64.8	79.6	75.4	65.9	64.7
Cellulose	33.9	33.9	39.4	39.8	34.7	34.6
Hemicellulose	28.5	27.7	35.4	31.0	27.8	26.4
Apparent digestibility (%)						
Organic matter	62.0	64.6	56.5	63.8	60.0	63.3
Crude protein	55.3	56.0	47.2	56.0	57.4	59.6
N D F	69.0	77.2	63.5	72.6	49.8	69.3
Cellulose	70.7	78.1	68.8	76.6	50.4	69.9
Hemicellulose	70.6	80.9	62.1	75.6	51.0	73.9
Nutritive value (%, DM)						
D C P	6.5	9.7	5.0	8.7	6.4	10.1
T D N	57.1	59.2	54.0	61.0	55.3	58.4
Dry matter intake/4 wethers						
kg/day	5.6	6.3	5.3	6.0	6.1	6.2
±S.D	0.2	0.3	0.3	0.2	0.2	0.6

NDF : Neutral Detergent Fiber, DCP : Digestible Crude Protein, TDN : Total Digestible Nutrient.

Table 2 Effect of ammoniation on the qualitative improvement of barley, wheat and oat straw[a]

Item	Barley straw		Wheat straw		Oat straw	
	Untreated	Treated[b]	Untreated	Treated[c]	Untreated	Treated[d]
Chemical composition (%, DM)						
Crude protein	2.0	6.2	4.9	9.3	2.2	5.5
N D F	82.0	76.2	76.6	76.0	82.3	79.4
Cellulose	45.4	49.5	40.7	43.1	46.1	48.3
Hemicellulose	29.0	16.8	30.0	25.1	29.0	22.6
Apparent digestibility (%)						
Organic matter	47.6	54.2	50.3	53.0	50.8	55.7
Crude protein	25.0	33.2	29.0	46.4	26.1	30.0
N D F	49.4	61.7	52.1	54.5	51.0	62.3
Cellulose	56.6	66.7	58.5	59.3	56.0	68.3
Hemicellulose	47.3	76.1	52.3	59.3	52.2	70.9
Nutritive value (%, DM)						
D C P	0.5	2.1	1.4	4.3	0.6	1.7
T D N	43.9	50.2	46.2	48.7	48.1	52.3
Dry matter intake/4 wethers kg/day	3.1	3.9	3.0	3.7	3.0	3.8
±S.D.	0.2	0.2	0.4	0.2	0.1	0.2

[a] By combine harvester
[b] 2.5% NH_3, 64.5% moisture
[c] 2.0% NH_3, 54.5% moisture
[d] 2.0% NH_3, 45.0% moisture

Table 3 Effect of ammoniation on the qualitative improvement of rice straw

Item	Field-cured straw		Straw silage
	Untreated	NH_3 2 % treated	
Moisture content (%)	14.0	33.0	65.7
Chemical composition (%, DM)			
Crude protein	5.2	7.5	4.8
N D F	67.2	66.1	65.8
Cellulose	35.8	36.2	35.3
Hemicellulose	27.9	26.0	27.0
Apparent digestibility (%)			
Organic matter	46.0	51.4	46.6
Crude protein	47.1	48.1	58.6
N D F	46.3	51.9	47.4
Cellulose	50.8	57.9	52.0
Hemicellulose	46.2	50.3	46.6
Nutritive value (%, DM)			
D C P	2.4	3.6	2.8
T D N	37.0	41.6	38.1
Dry matter intake/4 wethers kg/day	3.5	4.9	4.4
±S.D	0.3	0.2	0.3

residues.

The experimental results showing that ammoniation improved the chemical composition, digestibility, nutritive value and dry matter intake of the roughages are illustrated in Tables 1, 2 and 3.

Discussion

Toutain, B. (GERDAT): Have you carried out an economic analysis to compare the cost of various sources of nitrogen products that could be used in your method, for example urea ?

Answer: In the future we plan to carry out such studies.

Siregar, M.E. (Indonesia): I was impressed by the improvement of the quality of orchard grass after treatment with ammonia compared with the untreated materials. Could your method be applied economically by the farmers ?

Answer: One of the drawbacks is the comparatively high cost of ammonia. Indeed higher amounts of ammonia are required if the water content of the materials exceeds 40%.

Mendoza, R.C. (The Philippines): Could the size of the bale affect the efficacy of ammonia treatment from the economic point of view ?

Answer: The volume of the material might increase, which would not improve the efficacy.

Mendoza, R.C. (The Philippines), **Comment:** If the size of the bale were smaller, the penetration of ammonia might be better.

Cocks, P.S. (ICARDA):Was the improvement of the quality of hay reflected in the performance od the animals ?

Answer: Such experiments have not been performed in Japan but data from the USA indicate a significant improvement of the performance of the animals.