Livestock Research for Rural Development **Volume 5, Number 3, December 1993**

Ammoniation of straw using urea, ammonia gas or ammonium hydroxide

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Summary

Chopped cereal straw (3 sacks/treatment) was treated in polyvinyl chloride (PVC) sacks (1.5 m diameter, 2.8 m height and 0.5 to 0.8 mm thickness) with urea-solution (10% urea solution at the rate of 400 litres/100 kg straw), NH_4OH (12 litres of 25% NH_3 by weight/100 kg straw) or NH_3-gas (3 litres/100 kg straw). In another test, the effect of straw moistening (none, 8 or 16 litres of water/100 kg) on the efficiency of NH_3 gas in upgrading straw was studied. All chemicals significantly increased the *in vitro* organic matter digestibility (control 40.2%, NH_3 gas 55.2%, NH_4OH 53.9% and urea 51.5%) and content of N x 6.25 (control 37, NH_3-gas 109, NH_4OH 104 and urea 122 g/kg DM) of straw. Moistening of straw did not affect the digestibility (no water 55.2%, 8 litres water 55%, 16 litres water 54.8%) or CP content (no water 107, 8 l water 112, 16 l water 108 g CP/Kg DM). For all three chemicals there was no difference in straw digestibility whether it was taken from the top, middle or bottom of the sack and/or at the beginning, middle or end of the radius.

KEY WORDS: Barley straw, ammoniation, urea, ammonia gas, ammonium hydroxide, digestibility

Introduction

Cereal straws are produced in considerable quantities in many countries representing the most widely underutilized source of carbohydrates. The limited use of cereal straws is due to their low voluntary intake and low digestibility, associated with high lignin content, the manner in which this indigestible material is bound to the digestible cellulose and hemicellulose, and the low nitrogen concentration (Coxworth *et al* 1977).

Chemical treatment of crop residues with various alkalis has increased digestibility and often has increased voluntary intake and animal performance (Jackson 1978). Use of ammonia gas, ammonium hydroxide and urea has attracted considerable attention in recent years (Sundstol and Coxworth 1984) as a means of adding nitrogen and increasing digestibility and voluntary intake simultaneously.

The present paper reports on the effect of ammonia gas, NH_4OH and urea in upgrading the nutritional value of straw.

Materials and methods

Polyvinyl chloride (PVC) sacks (1.5 m diameter, 2.8 m height and 0.5 to 0.8 mm thickness) were used for storing/treating chopped straw. Three sacks (replicates) were used per treatment. Sacks were filled with straw and sealed prior to injection of NH_3 gas and or sealed after the injection with water, NH_4OH and urea solution. Injection of water or NH_4OH was made in three heights using a perforated metal pipe and a hand operated pump.

The treatments were: (US) untreated straw, (NH_3) straw injected with ammonia gas, ($8NH_3$) straw moistened with 8 litres of water/100 kg straw and injected with ammonia gas, ($16NH_3$) straw moistened with 16 litres of water/100 kg straw and injected with ammonia gas, (NH_4OH) straw injected with NH_4OH and (Urea) straw sprayed with urea solution.

Water and NH_4OH were injected through a perforated metal pipe placed in the centre of the sack through its top (mouth). Pumping of water/solution was done at three different heights. The sack was sealed following the spraying of urea solution (10% urea solution at the rate of 400 ml/kg straw) and/or injection of NH_4OH. Twelve litres of 25% NH_3 by weight, 3 litres ammonia gas and 40 litres of 10% urea solution were used per 100 kg straw.

NH_3 gas was injected through a perforated metal pipe which was pressed through the PVC and into the middle of the sack. The hole left in the PVC sack after the withdrawal of the pipe was sealed with tape. The ammonia bottle was upside down on a rack placed on a platform balance and the ammonia was added by weight.

The PVC sacks were opened 42 days after treatment and samples of straw were taken at three heights (top, middle, bottom of the sack) and at each height at three points of the radius (centre, middle, end of radius). Samples at all heights were taken following 24 h aeration.

Samples of straw were exposed to air for 24 h before being dried (55 C), ground (1 mm) and analysed for total N (AOAC 1975). Digestibility in vitro was determined on the samples following the method of Tilley and Terry (1963). The data were analysed by one- way analysis of variance (Steel and Torrie 1960).

Results and discussion

There was no mould development in any of the treatments. When water was injected at different points in the centre of the sack the colour of straw was variable being darker for the moistened straw treated with NH_3 gas. Similarly, straw injected with NH_4OH was darker close to the centre of the sack. There was no difference in the ammonia smell of straw treated with NH_4OH or ammonia gas. Contrary, ammonia smell was weaker in the urea-treated straw.

The point of sampling for a particular chemical did not affect the in vitro digestibility of treated straw (Table 1). There were however, significant differences in the N x 6.25 content which was higher ($P<0.05$) on the top compared to middle and bottom for ammonia gas and urea treatment. In contrast, NH_4OH treated straw obtained from the bottom of the sack had a significantly ($P<0.05$) higher N x 6.25 content than that from the top point.

Table 1. Digestible organic matter and N x 6.25 content of straw obtained at different parts of the sack (Top, middle and bottom)

	Top	Middle	Bottom	SE
NH3				
N x 6.25 (g/kg DM)	115a	103b	104b	1.8
DOM (% of DM)	55.2	54.6	54.6	0.38
NH4OH				
N x 6.25 (g/kg DM)	89b	104ab	118a	8.1
DOM (% of DM)	49.8	54.3	57.5	2.22
Urea				
N x 6.25 (g/kg DM)	200a	97b	92b	17.7
DOM (% of DM)	56.7	49.9	49.3	2.55

abc: Means in the same line with different superscripts differ significantly.

All chemicals were effective in increasing ($P<0.001$) the N x 6.25 content and the in vitro digestibility of straw (Table 2). There were no significant differences, however, between chemicals, for in vitro digestibility, and nitrogen retained in the straw.

The similarity of results with aqueous and anhydrous NH_3 is in line with the data of Sundstol *et al* (1978) and Orskov *et al* (1983). Furthermore, the higher proportion of N retained with urea than NH_3 gas is in line with the data of MacDearmid *et al* (1988) but at variance with those of Joy *et al* (1992).

Addition of water to dry straw did not affect the effectiveness of ammonia gas in increasing the digestibility and the nitrogen content of treated straw (Table 3). This is at variance with the findings of Wais et al (1972) and Sundstol *et al* (1979) where addition of water before treatment enhanced the ammoniation process. Harton and Steacy (1979), however, underlined the impracticability of adding water in the straw prior to treatment. Furthermore, in the studies of Mandell *et al* (1988), addition of water to raise the moisture content of wheat straw up to 25% did not result in significant improvements over straw ammoniated at 15% moisture. Similarly, chemical treatment at 30% moisture resulted in limited improvements in the digestion of DM and OM.

Table 2. The effect of chemical on the nutritive value of cereal straw

	No. of observations	N x 6.25 (g/kg DM)	DOM (% of DM)
Treatment			
Untreated	3	37b	40.2b
NH_3-gas	9	109a	55.2a
NH_4OH	9	104a	53.9a
Urea	9	122a	51.5a
SD		33.6	3.86

ab: Means in the same column with different superscripts differ significantly.

Table 3. The effect of added water on the efficiency of ammonia (NH3) gas in upgrading cereal straw

	No of observations	N x 6.25 (g/kg DM)	DOM (%)
NH_3-gas	9	107	55.2
NH_3-gas + water			
8 litres	9	112	55.0
16 litres	9	108	54.8
SE		2.6NS	0.97NS

It is concluded that all three chemicals (urea solution, anhydrous or aqueous ammonia) are equally effective in upgrading the nutritional value of straw and that selection of the chemical will depend upon the available infrastructure which in the case of urea and aqueous ammonia is cheap and simple.

Acknowledgements

The authors are grateful to the FAO and UNDP offices in Damascus, to Drs S Badawi (Chief AGON,FAO, Rome), R Sancousy (Feed Resources, AGAP, FAO, Rome) and K Qamar (AGON, FAO, Rome) for continuous support and encouragement and to his Excellency the Minister of Agriculture and Agrarian

Reform and his staff for making available all necessary facilities for the implementation of this work. This work was carried out in conjunction with the Greater and Improved Use of Agricultural Residues for Animal Feeding Project, a joint undertaking between the Government of Syria and the UNDP and FAO.

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(Received 1 July 1993)