KINETICS OF DIGESTION OF AMMONIATED WHEAT STRAW: FACTORS INFLUENCING VOLUNTARY STRAW INTAKE BY CATTLE AND SHEEP

J. Zorrilla-Rios[1], C.L. Streeter[2] and G.W. Horn[3]

Story in Brief

In order to achieve a better understanding of mechanisms responsible for higher voluntary intake of ammoniated wheat straw, data were obtained on the effect of ammoniation on the easiness of straw breakdown (fragility), in vitro digestibility (IVDMD) and rate of particulate passage from the rumen of cattle and sheep. Two methods of ammoniation, dry (S-A) and wet (HMAS) were compared. In the sheep trial, the effect of level of moisture of HMAS was investigated by offering this treatment also in the dry form (DHMAS). Both methods of ammoniation caused an increase ($P<.05$) in crude protein and IVDMD, and a reduction in the hemicellulose content ($P<.01$). Cattle and sheep had a faster rate of passage ($P<.05$) of ruminal particulate matter under S-A as compared to U-S. HMAS had a further 22 percent increase over S-A in cattle, with no effect in sheep. Voluntary feed intakes as compared to U-S intakes, were increased by DHMAS only in sheep with no effect by HMAS in sheep and a reduction in cattle. Strong ammonia odor in HMAS was considered to be partially responsible for the effect in intake. Voluntary intake of straw is explained in terms of chemical, physical and physiological factors and possible application of wet ammoniation followed by a drying process is considered.

Introduction

The level of production achieved by ruminants under dietary regimens based on roughages is highly dependent on the level of intake. Identification and manipulation of factors limiting the ruminant's capacity to consume forage will have a positive effect on the efficiency of production of meat, milk and/or wool. The present experiments were conducted to study the influence of ammoniation of wheat straw on some factors known to have an effect on intake, such as fragility, in vitro digestibility and rate of passage of ruminal digesta of cattle and sheep fed wheat straw ammoniated with and without added water.

Material and Methods

Preparation of Ammoniated Straw. Wheat straw was treated by three methods prior to feeding: untreated (U-S), stack ammoniation (S-A) and high moisture ammoniation (HMAS). Untreated straw was stored as large square bales (3.94 ft x 7.87 ft). Thirty-six of the untreated bales were ammoniated by the stack method (4 percent anhydrous ammonia of the "as is" straw weight). Dry ammoniated bales were removed from the covered stack as needed for feeding, ground in a tub grinder and stored in a covered building. Another 36 untreated bales were ground, weighed into a feed wagon, and water was added to increase straw

[1]Research Associate [2]Former Research Associate [3]Professor

moisture content to 60 percent. The wetted straw was delivered into a double walled plastic bag (Ag Bagger, Kates), where it was compressed and stored. On the following day, anhydrous ammonia was added to the contents of the bag at a rate of 4 percent of the original "as is" straw weight. Ammonia was injected into the bag through a pointed galvanized pipe (7.87 ft long x .75 in diameter) with .06 in holes drilled through the pipe every 11.8 in. Fifteen injections were made along the length of the bag. The wet ammoniated straw was removed from the bag daily, mixed in a feed wagon and fed directly. All types of straws were stored under cover for two months prior to feeding.

Experiment 1. Seventy-two three-quarter Hereford or Angus, one-quarter Simmental heifer calves, weighing 513 lb were randomly assigned to one of the following treatments: ad libitum U-S, S-A or HMAS straw each supplemented with either 3.96 or 5.28 lb/head/day of one of the two supplements shown in Table 1. Both supplements were formulated and fed to meet the protein requirements of a heifer gaining 1.54 lb (NRC, 1976). The low and high levels of supplement were formulated to meet 30 and 50 percent of the heifer's TDN requirements, respectively. The supplements were offered each morning prior to feeding the straw.

Table 1. Ingredient composition (% dry matter basis) of supplements and level of feeding.

	Supplements	
Ingredient	1	2
Soybean meal	70.0	40.0
Ground shelled corn	21.4	52.4
Dicalcium phosphate	2.0	1.0
Limestone, ground	1.0	1.0
Trace mineralized salt	.5	.5
Sugarcane molasses, dehydrated	5.0	5.0
Crude protein, %	38.2	25.8
Level of supplementation, lb/head/day		
Cattle	3.96	5.28
Sheep	.55	--

Experiment 2. Twelve yearling wethers and four yearling ewes (average weight of 72 lb) were randomly assigned within sex, to four straw treatments. In addition to the three treatments described in Experiment 1, a portion of the wet ammoniated straw was placed in a forced air oven at 80 C for 24 hr to remove moisture and free ammonia prior to feeding (DHMAS). All four straws were fed ad libitum with .55 lb of supplement 1 (Table 1). The treated straw had been stored under cover 6 months prior to this trial. Feed refusals were recorded and removed daily. The next day's allowance was adjusted to provide 20 percent more than was consumed on the previous day.

Determination of crude protein (Nx6.25), fiber fractions, IVDMD and fragility were conducted on dried, ground samples of all treated straws except for HMAS. Total nitrogen and fiber fractions of HMAS were estimated on wet samples (frozen and thawed before analysis), and IVDMD and fragility were not determined. Fragility of straws was estimated by grinding 10 g samples for 20 seconds in an electric coffee mill (Varco Inc., 1 Montogomery Street, Belleville, NJ 07109. Model 228.1.00) and dry sieving for 10 minutes through two sieves with pore diameter of 0.5 and 1.0 mm, respectively. The dry weight retained between the two sieves was expressed as a percentage of the total sample and used for treatment comparisons. Rate of passage of ruminal digesta in cattle and sheep was determined by a pulse dose procedure with periodic fecal sampling after dosage. Representative samples of straw for each treatment were labeled with $YbCl_3$ by the immersion and rinsing procedure described by Teeter (1981). Approximately 150 and 15 g of Yb-labeled straw (as-fed) containing 4 and .4 g of $YbCl_3$ respectively, were fed to cattle and sheep, respectively, immediately before the morning feeding. Fecal samples were obtained from each animal at 24, 48, 72 and 96 hr after feeding the Yb-labeled straw. Ytterbium concentrations of straw and fecal samples were determined by atomic absorption spectroscopy under nitrous oxide flame, following ashing of individual samples. Rate of passage of particulate rumen digesta was calculated as the slope of the log of fecal Yb concentration vs time.

Results and Discussion

Results are summarized in Table 2. HMAS or DHMAS were more effective than S-A in terms of chemical measurements, fragility and IVDMD. Dry ammoniation increased crude protein and decreased hemicellulose, but had no effect on fragility and IVDMD compared to untreated straw. Drying the HMAS straw caused a significant loss of total nitrogen. Rate of passage of digesta in sheep was similar for both methods of ammoniation and higher than U-S ($P<.05$). In cattle, HMAS increased ($P<.01$) rate of passage over S-A, which in turn was higher ($P<.01$) than U-S. Level of supplementation in cattle had no effect on rate of passage of digesta. Straw intakes (percent BW) of U-S and S-A were similar within species. However, cattle ate less HMAS than S-A or U-S ($P<.05$). This negative response was attributed to a strong ammonia odor detected at the feeder's level with HMAS. This explanation is supported by the marked increase in intakes observed in sheep fed DHMAS and the loss of N as free ammonia from HMAS during the drying process (Table 2). Although levels of supplementation had no effect on voluntary intake of straw (6.87 high vs 7.08 low, lb DM/head/day), the degree to which supplementation itself precluded differences in intake to become apparent among U-S and S-A, cannot be assessed in the present trial since a control treatment without supplementation was not included. It is interesting to observe that the lack of intake response with S-A vs U-S was associated with a nonsignificant effect of the dry method of ammoniation on fragility and IVDMD of the treated straw, even though crude protein, solubilization of hemicellulose and digesta rate of passage were increased. In the absence of undesirable organoleptic factors (such as strong ammonia odor), voluntary intake of wet ammoniated straw was increased ($P<.01$) as observed for DHMAS in sheep. Anhydrous ammonia diffuses rapidly and efficiently in water, hence wetting the straw at the time of ammoniation may have enhanced the extent and degree of contact of ammonia with the fiber. This is demonstrated by the increased fragility and IVDMD of DHMAS in comparison to S-A. Once the strong smell of ammonia present in HMAS was eliminated (DHMAS), the benefit of wet ammoniation on voluntary intake became apparent. The easiness with which ingested particles are reduced in

Table 2. Effect of method of ammoniation of wheat straw on chemical composition, fragility, in vitro digestibility (IVDMD), rate of passage of particulate matter and intake.

Item	Treatments				OSL*
	U-S	S-A	HMAS	DHMAS	
Chemical composition, % DM					
Crude protein	3.3[a]	6.5[b]	23.8[c]	7.6[b]	P<.01
Ammonia nitrogen	.02[a]	.43[b]	2.58[c]	.27[ab]	P<.01
Hemicellulose	30.7[a]	26.6[b]	16.0[c]	17.0[c]	P<.01
Fragility					
% particles <1 mm	39.4[a]	40.6[a]	--	42.1[b]	P<.05
IVDMD, %	30.5[a]	38.8[a]	--	47.5[b]	P<.05
Rate of passage, %/h					
Cattle	2.9[a]	3.5[b]	4.3[c]	--	P<.01
Sheep	1.8[a]	3.3[b]	2.7[ab]	3.2[b]	P<.05
Straw intake, % BW					
Cattle	1.22[b]	1.31[b]	1.09[a]	--	P<.05
Sheep	.85[a]	1.08[a]	.92[a]	1.72[b]	P<.01

*Observed significance level.

size (fragility), affects exposure of potentially digestible substrate to microbial attack and the rate that the undigestible portion of feed reaches a small enough size to exit the rumen. An increased rate of passage is a reflection of decreased residence time of undigestible particles in the rumen. Voluntary intake of roughage diets by ruminants is largely controlled by its rate of disappearance from the rumen, which in turn is determined by the extent and rate of digestion of dry matter and rate of clearance of the undigestible fraction out of the rumen. Therefore, the higher intakes of ammoniated low quality roughages by ruminants can be partially attributed to the following factors: 1) an increased availability of nutrients by solubilization of hemicellulose, 2) swelling of the fiber, 3) greater surface area available for microbial attack, 4) additional supply of nitrogen for growth of ruminal microorganisms, and 5) a faster rate of removal of the undigestible fraction from the rumen. The response observed with wet ammoniated straw offered in the dried form (DHMAS), over the conventional stack method, justifies further research on this and alternative procedures for the treatment of low quality roughages. To what extent it may be feasible in practice to increase the moisture content of straw before ammoniation, and dry it off again before feeding, it is difficult to foresee at the present time. Biological justifications need to be assured before mechanical limitations are considered. Economical considerations will depend on particular circumstances and would have to be made accordingly.

Literature Cited

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