



Effects of urea and aqueous ammonia treatment on the nutritive value of triticale straw

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Abstract

A study was conducted to investigate changes in nutritive value of triticale straw (TS) treated with urea and aqueous ammonia. TS was chopped into pieces, approximately 2 cm in length. Solutions of feed grade urea and aqueous ammonia were applied to 800 g dry matter (DM) of chopped TS at rates of 0, 1.5, 3.0 and 4.5% (w/w). The chemicals were applied as aqueous solutions which added 800 g of water/800 g of TS DM, thoroughly mixed, stored in plastic containers and kept for 45 days at ambient temperature (22–25°C). There were four replicates of each treatment. Chemical composition and *in vitro* digestibility of test materials were determined. The amounts of pH, crude protein (CP) and NH₃-N increased ($P<0.05$) when urea and aqueous ammonia were applied at all rates. As a point of CP, the rates of 1.5 and 3.0% in urea-treated TS (UTS) were equivalent to the rate of 3.0 and 4.5% in aqueous ammonia-treated TS (ATS). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) content decreased ($P<0.05$) when urea and aqueous ammonia were applied at rates of 3.0 and 4.5%. There was a tendency for treatments to decrease acid detergent lignin (ADL), but the reduction was not significant. UTS had higher *in vitro* digestibility of DM (IVDMD), organic matter (IVOMD) and OM in DM (IVDOMD) than ATS. As a point of IVDMD, the rate of 1.5% in UTS treatments was equivalent to the rate of 3.0% in ATS treatments. Feed grade urea and aqueous ammonia can improve chemical composition and *in vitro* digestibility of TS, but effects of urea were better than those of aqueous ammonia.

Key words: Nutritive value, triticale straw, aqueous ammonia, urea.

Introduction

Straw is the most abundant of all agricultural residues in Iran, and despite its very low digestibility, a significant amount of it is fed to ruminants. Ammoniating is one of the most studied chemical treatments to improve forage quality. Ammoniation improves forage digestibility due to the hydrolytic action of ammonia on linkage between lignin and structural polysaccharide, which increases organic matter (OM) potentially available for utilization by ruminal microorganisms¹⁹. Ammoniation also increases the crude protein (CP) concentration of forage through fixation of applied N⁵.

Triticale (*Triticosecale*) is a man-made crop developed by crossing wheat (*Triticum turgidum* or *Triticum aestivum*) with rye (*Secale cereale*)¹⁵. Triticale variety is stable, it will not revert back to produce rye or wheat plants. The objective behind making wheat/rye crosses is to capture the best traits of each species. Wheat yields and grain quality are better than for rye, but rye has greater disease resistance and better tolerance of environmental stresses¹⁰. Interest in triticale has developed around two areas of potential use for grain. The first area of interest is for use as a feed grain because it is proven to be a good source of protein, amino acids and B vitamin. It has shown promise as both a forage crop and an alternative protein source in formulated rations for monogastrics, ruminants and poultry. The average *in sacco* degradability of 5 varieties of triticale straw was 42.4% (29.8-51.9%)⁹. The *in vitro* digestibility of triticale straw is 46% DM

basis¹⁷. When cereal straw (containing triticale straw) is treated with urea (55 g kg⁻¹ air-dry straw, in sealed bags at 22°C for 60 days) the average dry matter loss was 137 (range 87-192 g kg⁻¹ DM)⁶. Triticale grains contain more crude protein but considerably less crude fiber than barley grains, and the composition of the respective straw was similar². A lot of researchers have reported urea or ammonia treatment can improve the digestibility, crude protein content and other useful characteristics of cereal straw. The objectives were to examine the effects of aqueous ammonia and urea treatment on the chemical composition and *in vitro* digestibility of triticale straw.

Materials and Methods

The triticale straw (TS) used in the following experiments was obtained from non-irrigated, N-fertilized fields under inland, cold semi-arid climate (altitude 1320 m; 30-year mean precipitation 311 mm; mean number of days with frost 125) in north-west of Iran (38°25'N, 48°30'E). Soil texture was silty clay loam (silt 55%, clay 28% and sand 17%), pH 7.8, organic carbon 5 g kg⁻¹, N 0.4 g kg⁻¹, C/N ratio 12.5, CaCO₃ 17 g kg⁻¹, available P 20.6 mg kg⁻¹ and available K 450 mg kg⁻¹. TS collected from several fields were chopped into pieces (about 2-cm long) and mixed completely. Solutions of feed grade urea and aqueous ammonia were applied to 900 g (800 g DM) of chopped TS at rates of 0, 1.5, 3.0 and 4.5% (w/w). The chemicals were applied as aqueous solutions which

added 800 g of water/800 g of TS DM. The solutions were poured over the TS in a tub and mixed for approximately 3 min. Then the resulted material was moved to the plastic containers and air was removed by compression. Treated TS was sealed and stored at ambient temperature (22-25°C) for 45 days. There were four replicates of each treatment.

At the end of the storage period, samples were exposed to free air, in shadow for 24 h for excess NH₃ to escape but 200 g of each sample was separated immediately for determination of pH and -NH₃-N. The residual samples were oven-dried at 55°C for 72 h. For determination of pH, 100 ml of deionized water was added to 100 g of each fresh sample, mixed and shaken for 2 min, juice obtained by compression and pH measured with a pH meter²⁵. NH₃-N was measured from fresh samples by the procedure described by Huber *et al.*¹⁴. Samples of 200 g oven-dried forage from each treatment were ground in a Wiley mill (1 mm screen) and used for subsequent chemical analysis. Dry matter (DM), crude protein (CP), ether extracts (EE), ash, acid detergent fiber (ADF) and acid detergent lignin (ADL) contents of samples were determined by standard methods¹. Neutral detergent fiber (NDF) was analyzed according to Van Soest *et al.*²⁴. Non-fibrous carbohydrates (NFC) were calculated¹⁸ as follows: NFC = 100 – (CP % + NDF % + EE % + Ash %).

In vitro DM digestibility (IVDMD), organic matter digestibility (IVOMD) and digestible OM in DM (DOMD) were determined according to the two-stage technique of Tilley and Terry²² with rumen liquor collected by stomach tube suction aided by vacuum pump from mature Iranian Taleshi cows. These cows with average weight of 350 kg were fed alfalfa hay and 2 kg each of common concentrate two weeks before commencement of the experiment and during collection period. Animals were not fed before rumen liquor was collected. The liquor was collected in flask immersed in warm water maintained at 39°C, strained through three layers of cheese cloth and CO₂ bubbled slightly through it before dispensing into 100 ml tubes. Provided data was submitted to analysis of variance by using the SAS software²⁰ for completely randomized designs and LSD's test for multiple comparisons among means (p<0.05).

Results and Discussion

Chemical compositions of urea-treated (UTS) and aqueous ammonia-treated (ATS) TS are shown in Table 1. Urea and aqueous ammonia increased ($P<0.05$) pH from 4.75 to 9.44 and from 4.74 to 6.12, respectively. The rate of 4.5% in UTS had higher pH. The rate of 1.5% in UTS was equivalent to the rate of 4.5% in ATS. The amounts of CP and NH₃-N increased ($P<0.05$) when urea and aqueous ammonia were applied at all rates. The rate of 4.5% in UTS had highest amount of CP, but control groups (rates of 0%) had lowest one. As a point of CP, the rates of 1.5 and 3.0% in UTS were equivalent to the rates of 3.0 and 4.5% in ATS treatments. However, the effect of urea was higher than that of aqueous ammonia. NH₃-N increased ($P<0.05$) in UTS and ATS, although ATS had low NH₃-N, also the rate of 1.5% in UTS was higher than the rate of 4.5% in ATS. NDF decreased ($P<0.05$) when urea and aqueous ammonia were applied at rates of 3.0 and 4.5%. Similarly this reduction occurred in the case of ADF but at the rates of 3.0 and 4.5% in UTS and 4.5% in ATS ($P<0.05$). There was a tendency for treatments to decrease ADL, but the reduction was not significant. Also other chemical components such as EE, ash and NFC were not significantly different.

In vitro digestibility coefficients of treated triticale straw are shown in Table 2. The rate of 4.5% in UTS had the highest digestibility, but control groups had the lowest one. IVDMD increased ($P<0.05$) in UTS and ATS when urea and aqueous ammonia were applied at rates of 3.0 and 4.5%. When urea and aqueous ammonia were applied at higher rate IVDMD increased 9.5 and 6.9% in UTS and ATS, respectively, compared with control. IVOMD and IVDOMD increased ($P<0.05$) only in UTS when urea was applied at rates of 3.0 and 4.5%, but in ATS differences among means of all rates were not significant.

Increasing of nitrogenous fractions and *in vitro* digestibility of TS are similar to previously reported research about TS⁶ and straw of other cereals such as wheat, barley, oat and rice. Dryden and Leng⁷ recorded that the cell wall OM content of barley straw was least at the highest levels of ammonia (45 g/kg DM) used in their experiment. Mason *et al.*¹⁶ reported the lowest concentrations of cell wall constituents and the highest OM

Table 1. Mean chemical composition of treated triticale straw (based on dry matter).

Parameter	Urea (%)				Aqueous ammonia (%)			
	0	1.5	3.0	4.5	0	1.5	3.0	4.5
pH	4.75 f	5.97 c	8.65 b	9.44 a	4.74 f	5.25 e	5.66 d	6.12 c
N-NH ₃ (mg/kg)	778.3 g	3234.5 c	5541.5 b	7837.3 a	775.0 g	1235.5 f	1763.0 e	2837.5 d
CP %	2.12 e	3.10 c	3.94 b	5.26 a	2.12 e	2.65 d	3.14 c	3.58 b
EE %	1.17	1.05	0.99	1.10	1.06	0.96	1.07	1.20
Ash %	9.73	9.67	9.87	9.94	9.92	9.52	9.74	9.88
NDF %	84.95 a	83.98 ab	83.04 bc	82.31 c	84.80 a	83.90 ab	83.27 bc	83.18 bc
ADF %	54.78 a	53.15 ab	52.50 b	52.28 b	54.79 a	53.43 ab	53.09 ab	52.71 b
ADL %	9.58	8.79	9.10	8.71	9.21	8.75	8.99	9.14
NFC %	2.04	2.20	2.17	1.39	2.11	2.98	2.80	2.17

Dissimilar letters indicating significant difference at p<0.05.

Table 2. Mean *In vitro* digestibility coefficients of treated triticale straw (based on dry matter).

Parameter	Urea (%)				Aqueous ammonia (%)			
	0	1.5	3.0	4.5	0	1.5	3.0	4.5
IVDMD	34.56 de	35.73 bcde	36.92 ab	37.85 a	34.23 e	35.23 cde	35.90 bcd	36.60 abc
IVOMD	33.28 c	34.50 abc	35.34 ab	36.11 a	32.82 c	33.98 bc	34.12 bc	34.48 abc
IVDOMD	31.82 c	33.25 abc	33.93 ab	34.92 a	31.52 c	32.78 bc	32.98 abc	33.19 abc

Dissimilar letters indicating significant difference at p<0.05.

digestibility when wheat straw was treated with 80 g ammonia/kg DM and 400 g added water/kg DM. Similar results were recorded by Zaman *et al.*²⁶ who observed that the *in vitro* DM digestibility of barley straw was highest after the addition of 80 g of urea/kg of barley straw. Colucci *et al.*⁴ also found that oat and barley straws of initially lower digestibility responded better to urea treatment. Similar results in rice straw were reported by Vadiveloo²³ who observed that the rice varieties with poorer straw quality responded better to urea treatment with results predicting that straw with an initial IVDMD of 45 or 55% would have an IVDMD of 59 or 62% after urea treatment. Oji *et al.*¹⁹ reported nitrogenous fractions and *in vitro* digestibility of maize residues increased ($P < 0.05$) when treated with aqueous ammonia and urea at 3% of DM. Also in the case of N fractions there are reports elsewhere^{12,21}.

The urea which is used was hydrolysed by urease enzyme in triticale straw to NH_3 . It has been reported that urease activity demands optimal moisture content from over 375 g kg^{-1} DM³. Thus, at 800 g kg^{-1} DM moisture level, urea hydrolysis could be extensive. The relatively high values for NH_3 -N in the treated materials, despite aeration to void free NH_3 , could be explained by the physical changes in the cell wall of triticale straw that culminate in attachment of N as NH_3 .

The significant increase in CP concentration of TS could be of practical benefits. The CP concentration of the control groups (2.12%) would be inadequate for the requirements of maintenance and growing sheep⁸, and so treating TS with urea would reduce the need to provide supplementary ruminal CP for these classes of livestock.

Additives make alkali condition in which effects of feed grade urea are more than those of aqueous ammonia. A trend for decreases in NDF, ADF and ADL fractions was observed in this experiment. Correspondingly, the *in vitro* digestibility increased in UTS and ATS. These results are similar to previous report about maize residues¹⁹. These declines ($P < 0.05$) in concentrations of NDF are consistent with the generic action of ammonia on feedstuffs^{5,13}. The reduction in fiber content after treatment with ammonia was due to the reduction in hemicellulose which was constituted in the cell wall together with cellulose and lignin. During ammonia treatment lignin dissociated from the ligno-cellulosic complex but was still detected as lignin. Also various workers have adduced reasons for the improvements observed after ammoniation of cereal residues. They include collapse of vascular bundle sheath cells in treated rice straw, rupture of inner cuticular surfaces and separation from adjacent ground parenchyma when wheat straw was ammoniated, alteration in the friability of the rigid layer covering the inner surface of cell walls¹¹ and the ability of NH_3 to form an ammonia-cellulose complex and to decrease cellulose crystallinity. The latter workers argued further that any reduction in crystallinity of cellulose forming the microfibrils of the cell wall contributes to an increased fragility of the wall which consequently increases susceptibility to attack by cellulolytic microbes. These facts may explain the observed increase in *in vitro* digestibility with treated residues. Also, it is known that NH_3 has the ability to dissolve parts of hemicellulose, cleave ester bonds of uronic acids with loss of acetyl groups, thus releasing acetyl and phenolic acids, an effect that may possibly explain the decreases in NDF and ADF¹⁹. Rumen fill is a major limitation to the productivity of ruminants eating straw.

These reductions in NDF caused by ammonia treatment are encouraging because they imply that the degradability and intake of straw may be improved by chemical treatment.

Conclusions

Triticale straw has very low quality as a feed for livestock. While treatment of triticale straw with urea and aqueous ammonia caused changes in chemical compositions and *in vitro* digestibility, there were differences in effect between the urea and aqueous ammonia. Aqueous ammonia is definitely more technically cumbersome to handle and may expose the handler to health hazards while urea does not have these problems. Moreover, it is cheap. Even though ammonia sources are not as efficient as alkali compounds such as NaOH in improving the nutritive value of low quality roughages, the results obtained here and elsewhere suggest the use of urea for upgrading the N of poor quality crop residues.

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