Chemical composition and digestibility of urea-treated triticale (x *Triticeosecale* straw)

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Abstract

A study was conducted to investigate changes in chemical composition and digestibility of urea-treated triticale straw. Triticale straw (TS) was chopped into pieces, approximately 2 cm in length. In Experiment 1, Solution of urea was applied to 1000 g dry matter (DM) of chopped TS at rate of 4.0% (w/w). The urea was applied as aqueous solution which added 1500 g of water/1000 g of TS DM. Urea-treated TS in laboratory scale (TSL) was thoroughly mixed, stored in plastic containers and kept for 45 days at ambient temperature (20-25°C). Chemical composition and *in vitro* digestibility of TSL was determined and compared with TS and alfalfa hay (AH). The amount of total nitrogen (TN) and crude protein (CP) increased (P<0.05), but neutral detergent fiber (NDF) and acid detergent fiber (ADF) decreased (P<0.05) when TS was treated with urea. AH had the highest digestibility of TSL was determined and compared with TS and alfalfa hay (AH). The amount of total nitrogen (TN) and crude protein (CP) increased for 45 days at ambient temperature (10-25°C). An *in vivo* digestibility experiment was done using four mature Mohagni wether sheep. TSF had a higher (P<0.05) DM digestibility (DMD) and organic matter (OM) digestibility (OMD) values, compared with TS. However, TSF had greater digestible OM in the DM (DOMD), and metabolizable energy values, compared with TS, but these differences were not significant. Results showed that urea can improve chemical composition and digestibility values of TS.

Key words: Digestibility, *in vivo*, *in vitro*, triticale straw, urea.

Introduction

Triticale (x *Triticeosecale* Wittmack) is a man-made crop developed by crossing wheat (*Triticum*) with rye (*Secale*) 16. 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 yield and grain quality are better than for rye, but rye has greater disease resistance and better tolerance of environmental stresses 11. Interest in triticale has been 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 vitamins. It has shown promise as both a forage crop and an alternative protein source in formulated rations for monogastrics, ruminants and poultry. Bilgili reported that degradation levels of dry matter (DM) and crude protein (CP) were 59.0% and 58.5%, respectively, in whole plant triticale forage 2.

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. Cereal straw is a major source of animal feed, and the use of triticale for straw production usually surpasses the use of wheat (*Triticum sp.*) or barley (*Hordeum vulgare L.*) 19. 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 polysaccharides, which increases organic matter (OM) potentially available for utilization by ruminal microorganisms 21. Ammoniation also increases the CP concentration of forage through fixation of applied nitrogen (N) 6. The average *in sacco* degradability of 5 varieties of triticale straw (TS) was 42.4% (29.8-51.9%) 10. The *in vitro* digestibility of TS is 46% on DM basis 20. When cereal straw (including TS) is treated with urea (55 g kg⁻¹ air-dry straw, in sealed bags at 22°C for 60 days) the average DM loss was 137 (87-192) g kg⁻¹ DM 7. Triticale grains contain more CP but considerably less crude fiber than barley grains, and the composition of the respective straw is similar 2. A lot of researchers 7,8,17,20 have reported urea treatment can improve the digestibility, CP content and other useful characteristics of cereal straw. The objectives were to examine the effects of urea treatment on the chemical composition and *in vitro* and *in vivo* digestibility of TS.

Materials and Methods

The TS used in the 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 57%, clay 27% and sand 16%), pH 7.7, organic carbon 5 g kg⁻¹, N 0.4 g kg⁻¹, C/N ratio 12.5, CaCO₃ 19 g kg⁻¹, available P 23.6 mg kg⁻¹ and available K 470 mg kg⁻¹. TS collected from several fields was chopped into pieces (about 2-cm long) and mixed completely.
In Experiment 1, solution of feed grade urea was applied to 1120 g (1000 g DM) of chopped TS at rate of 4.0% (w/w). The urea was applied as aqueous solution which added 1500 g of water/1000 g of TS DM. The solution was poured over the TS in a tub and mixed for approximately 3 min. Then the resulted material was moved to plastic containers and air was removed by compression. Urea-treated TS in laboratorial scale (TSL) 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. 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 meter 24. 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. DM, total N (TN), CP, ash, acid detergent fiber (ADF) and acid detergent lignin (ADL) contents of samples were determined by standard methods 1. Neutral detergent fiber (NDF) was analyzed according to Van Soest et al. 26.

In vitro DM digestibility (IVDMD), organic matter (OM) digestibility (IVOMD) and digestible OM in the DM (IVDOMD) were determined according to the two-stage technique of Tilley and Terry 24 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.

In Experiment 2, solution of feed grade urea was applied to 224 kg (200 kg DM) of chopped TS at rate of 4.0% (w/w). The urea was applied as aqueous solution which added 3000 g of water/200 kg of TS DM. The solution was poured over the TS in farmyard and mixed for approximately 20 min. Then the resulted material was moved to the plastic drums (130 litres capacity) and air was removed by compression. The drums were lined with white polynethylene sheet. Treated TS in farm scale (TSF) was sealed and stored for 45 days at ambient temperature (10-25°C). At the end of the storage period, TSF was exposed to free air, in shadow for 24 h for excess NH₃ to escape but 200 g sample of each drum was separated immediately for determination of pH and chemical composition.

An in vivo digestibility experiment was done using the total faecal collection method 12. Four mature Moghani wether sheep of live weight 35±3 kg were used to measure DM digestibility (DMD), OM digestibility (OMD) and digestible OM in the DM (DOMD). Sheep were fasted for 12 h prior to weighing at the beginning and at the end of each experimental period. Two weeks before the start of the experiment, sheep were treated against internal parasites and supplied with an intramuscular injection of vitamins A, D and E. The animals were penned in individual metabolic cages that allowed separated collection of feces. They had free-access to water and salt stone. Three diets were used, one as basal diet (AH) and the rest as mixed diets (TS and TSF with AH). The diets were supplemented with the same amounts of minerals and vitamins premix (M+V). For 2 weeks (1 week for adaptation and 1 week for measurement), the apparent digestibility of AH alone was measured using the total faecal collection method with the same animals 12. After 7 days of adaptation period, the digestibilities of the mixed diets, which were offered simultaneously to the four animals, using a 2×2 change over design (two sheep for each mixed diet in each period). Seven days of adaptation period was used after each change, which lasted 7 days too. Animals were offered feed at maintenance level, 0.90 ± 0.15 kg−1 day−1 and the level of AH in each diet ranged from 50 to 60% of the total intake. The sheep were fed twice daily, around 08:00 and 17:00 h, and samples of feeds were taken daily for analysis of chemical composition. The faeces from each sheep on each treatment were weighed and a 10% sample was frozen at -20°C for later analysis. The digestibility of the TS and TSF was calculated by difference according to Givens et al. 12. The metabolizable energy (ME) values of the feeds were calculated using the following equation 16: ME (MJ/kg DM) = 0.016 × DOMD (g kg−1 DM).

Provided data from Experiment 1 was submitted to analysis of variance for completely randomized design and LSD test for multiple comparisons among means (p<0.05). For Experiment 2, collected data were analyzed as a 2×2 change over design using MIXED procedure. The SAS 22 package was used for all statistical calculations.

Results

Table 1 shows that AH was least and greatest (P<0.05) in OM and ash, respectively (897.2 and 102.8 g kg−1 DM, respectively) but these contents were in contrast to TSL and TS, which were greatest and lowest (P<0.05) in OM and ash, respectively.

AH had a greater (P<0.05) TN and CP compared with the TSL and TS, but these contents were least (P<0.05) for TS at 3.2 and 20.3 g kg−1 DM, respectively. TS had a greater (P<0.05) NDF and ADF compared with the TSL and AH, but this content was least (P<0.05) for AH. The ADL content was greatest (P<0.05) for AH at 98.9 g kg−1 DM, but this content was similar (no significant differences) for TSL and TS, among which TSL had the lowest content. The TN, CP, NDF and ADF contents of TSF were intermediate (P<0.05) to AH and TS. Mean moisture, DM and pH of TSF measured (n = 4) 622.0±7.6, 378.2±7.6 g kg−1 and 9.3±0.09, respectively.

AH had the highest (P<0.05) IVDMD, IVOMD and IVDOMD (Table 2) at 489.4, 468.0 and 460.7 g kg−1, respectively, but these values were lowest (P<0.05) for TS at 350.9, 336.2 and 323.6 g kg−1.

Table 1. Mean chemical composition of feeds (g kg−1 DM).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AH</th>
<th>TSL</th>
<th>TS</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OM</td>
<td>897.2 b</td>
<td>907.8 a</td>
<td>910.1 a</td>
<td>1.59</td>
</tr>
<tr>
<td>Ash</td>
<td>102.8 a</td>
<td>92.2 b</td>
<td>90.1 b</td>
<td>1.59</td>
</tr>
<tr>
<td>TN</td>
<td>23.7 a</td>
<td>10.7 b</td>
<td>9.0 b</td>
<td>0.34</td>
</tr>
<tr>
<td>CP</td>
<td>148.0 a</td>
<td>66.7 b</td>
<td>20.3 c</td>
<td>2.15</td>
</tr>
<tr>
<td>NDF</td>
<td>585.9 c</td>
<td>823.5 b</td>
<td>840.4 a</td>
<td>4.60</td>
</tr>
<tr>
<td>ADF</td>
<td>367.4 c</td>
<td>519.8 b</td>
<td>534.9 a</td>
<td>3.51</td>
</tr>
<tr>
<td>ADL</td>
<td>98.9 a</td>
<td>83.4 b</td>
<td>87.1 b</td>
<td>2.98</td>
</tr>
</tbody>
</table>

SEM Standard error of means. Means in the same row with different letters differ (P<0.05).

Table 2. Mean in vitro digestibility values of feeds (g kg−1 DM).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AH</th>
<th>TSL</th>
<th>TS</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVDMD</td>
<td>489.4 a</td>
<td>377.3 b</td>
<td>350.9 c</td>
<td>6.60</td>
</tr>
<tr>
<td>IVOMD</td>
<td>468.0 a</td>
<td>365.9 b</td>
<td>336.2 c</td>
<td>9.02</td>
</tr>
<tr>
<td>IVDOMD</td>
<td>460.7 a</td>
<td>354.6 b</td>
<td>323.6 c</td>
<td>8.07</td>
</tr>
</tbody>
</table>

SEM Standard error of means. Means in the same row with different letters differ (P<0.05).
DM, respectively. The in vitro digestibility values of TSL were intermediate to AH and TS.

Table 3 shows that TSF had a higher (P<0.05) DMD and OMD values compared with TS. However, TSF had a higher DOMD and ME values compared with TS, but these differences were not significant.

Table 3. Mean in vivo digestibility values and ME of feeds (DM basis).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TSF</th>
<th>TS</th>
<th>P value</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMD (g kg⁻¹)</td>
<td>425.7</td>
<td>384.3</td>
<td>0.0489</td>
<td>9.11</td>
</tr>
<tr>
<td>OMD (g kg⁻¹)</td>
<td>435.0</td>
<td>399.4</td>
<td>0.0352</td>
<td>6.87</td>
</tr>
<tr>
<td>DOMD (g kg⁻¹)</td>
<td>413.0</td>
<td>370.9</td>
<td>0.0638</td>
<td>10.74</td>
</tr>
<tr>
<td>ME (MJ kg⁻¹)</td>
<td>6.61</td>
<td>5.93</td>
<td>0.0638</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Discussion

When TS was treated with urea, TN, CP and in vitro digestibility values increased but DOMD and ADF decreased. There was a tendency for TSL to decrease ADL, but the reduction was not significant. Increase of N fractions and in vitro digestibility of TS are similar to previously reported research about TS and straw of other cereals such as wheat, barley, oat and rice. Dryden and Leng recorded that the cell wall OM content of barley straw was least at the highest level of ammonia (45 g/kg DM) used in their experiment. Mason et al. reported the lowest concentrations of cell wall constituents and the highest OM 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. 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. also found that oat and barley straw of initially lower digestibility responded better to urea treatment. Similar results in rice straw were reported by Vadiveloo who observed that the rice varieties with poorer straw quality responded better to urea treatment with results predicting that straw with an initial IVMD of 45 or 55% would have an IVMD of 59 or 62% after urea treatment. Oji et al. reported nitrogenous fractions and in vitro digestibility of maize residues increased (P<0.05) when treated with urea at 3% of DM. Also in the case of N fractions there are reductions in NDF caused by urea treatment are intermediate to AH and TS.

Triticale straw has very low quality as an agricultural by-product for ruminants. Urea treatment of triticale straw caused changes in chemical composition and improved digestibility values. 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 and digestibility of poor quality crop residues.

Conclusions

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References


Acknowledgements

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 walls and the ability of NH₃ 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 cellulytic microbes. These facts may explain the observed increase in in vitro digestibility with treated residues. Also, it is known that NH₃ has the ability to dissolve parts of hemicellulose and 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 ADF. Rumen fill is a major limitation to the productivity of ruminants eating straw. These reductions in NDF caused by urea treatment are encouraging because they imply that the degradability and intake of straw may be improved by urea treatment.


