# The effect of ammoniation by urea on the nutritive value of wheat straw for sheep

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Straw is a major by-product of the grain industry. Indirect ammoniation by urea to improve the nutritive value of straw was investigated. Ammoniated and untreated wheat straw were compared in a 2 × 2 factorial experiment at CP levels of 9 and 13%, using 20 adult SA Mutton Merino wethers.

Ammoniation improved voluntary intake and the apparent digestibility of OM significantly, by 27,3% ($P \leq 0,01$) and 7,1% ($P \leq 0,05$) respectively, resulting in a marked increase of 36,3% in DOM intake per $W^{0,75}$. The apparent digestibility of CF, CWC and hemicellulose were also significantly ($P \leq 0,01$) improved by ammoniation. The improvement in the apparent digestibility of ADF was not significant. CP level did not affect voluntary DM intake, but at the higher CP level apparent digestibility of OM, CF, ADF, CWC and hemicellulose were improved by 6,2; 6,5; 4,7; 5,4 and 4,1% respectively. This trend reached significance ($P \leq 0,05$) only in the case of OM and CF.

N-retention and the apparent digestibility of CP were significantly ($P \leq 0,01$) reduced by ammoniation. Because of the higher intakes obtained on the ammoniated diets DCP intake per $W^{0,75}$ was unaffected. N-retention and the apparent digestibility of CP were significantly ($P \leq 0,01$) improved at the higher CP level. Despite the reduction in CP digestibility and N-retention, ammoniation by urea seems to be a practical way to improve the nutritive value of low quality roughages.

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Strooi is 'n belangrike neweproduk van die graanbedryf. Die invloed van indirekte ammoniakbehandeling (deur ureum) op die voedingswaarde van koringstrooi is ondersoek. Behandelde en onbehandelde koringstrooi is in 'n 2 × 2 faktoriaaleksperiment met 20 volwasse SA Vleismerinohamels by ruproteïen (RP)-peile van 9 en 13% vergelyk. Ammoniakbehandeling het die vrywillige inname en skynbare organiese materiaal (OM) verteerbaarheid betekenisvol verhoog met onderskeidelik 27,3 ($P \leq 0,01$) en 7,1% ($P \leq 0,05$). Gevolglik is 'n aansienlike verhoging van 36,3% in verteerbare OM-inname per kg metaboliese massa ($W^{0,75}$) verkry. Die skynbare verteerbaarheid van ruvesel (RV), selwande en hemisellulose is ook hoogsbetekenisvol ($P \leq 0,01$) verhoog deur ammoniakbehandeling, terwyl die verteerbaarheid van suurbestande vesel (SBV) nie- betekenisvol verhoog is. RP-peil het nie vrywillige inname betekenisvol beïnvloed nie, terwyl verhogings van onderskeidelik 6,2; 6,5; 4,7; 5,4 en 4,1% in die skynbare verteerbaarheid van OM, RV, SBV, selwande en hemisellulose verkry is op die hoër proteïen-peil. Die neiging was betekenisvol ($P \leq 0,05$) slegs in die geval van OM en RV.

N-retensie en die skynbare RP-verteerbaarheid is hoogsbetekenisvol ($P \leq 0,01$) verlaag deur ammoniakbehandeling. As gevolg van die hoër vrywillige inname waargeneem op die behandelde rantsoene, was die verteerbare RP-inname per $W^{0,75}$ onveranderd. N-retensie en RP-verteerbaarheid is hoogsbetekenisvol ($P \leq 0,01$) verhoog by die hoër RP-peil. Ten spyte van die verlaging in RP-verteerbaarheid en N-retensie, blyk dit dat indirekte ammoniakbehandeling deur ureum 'n praktiese wyse is om die voedingswaarde van laegraadse ruvoere te verhoog.

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## Introduction

Cereal straw is a major by-product of the grain industry. Methods to improve the nutritive value of this low-protein, fibrous by-product for livestock have frequently been investigated. These methods are either chemical or physical (mechanical, heat or pressure) treatments, or combinations thereof. The chemical reagents most frequently used are sodium hydroxide (Jackson, 1977) and ammonia (Sundstøl, Coxworth & Mowat, 1978).

Large parts of the Western Cape are wheat-growing areas, where considerable amounts of cereal straw are produced. Cost and availability considerations have made the sodium hydroxide treatment the most frequently used in this area.

An indirect ammonia treatment, where straw is ensiled with an aqueous solution of urea, is described by Van der Merwe (1976); Kritzinger & Franck (1981) and Hadjipanayiotou (1982). The treatment depends on urease activity in plant materials to release ammonia from the urea. An advantage of this treatment is that urea is relatively safe and easy to handle compared to ammonia and sodium hydroxide. Furthermore the treatment is relatively simple, while the nitrogen content of the straw is increased. The relatively long period of time (approximately six weeks) required for optimal treatment, may be a disadvantage under certain conditions. Nevertheless it seems to be a promising technique of improving the palatability and digestibility of low quality roughages.

Seen against this background, an intake and *in vivo* digestibility trial was conducted on untreated and treated wheat straw. The effect of supplemental protein and the interaction between ammoniation and protein level were also investigated simultaneously.

## Materials and Methods

Ground (18 mm sieve) wheat straw was thoroughly mixed with a urea solution, to provide a urea and moisture level of 75 g/kg and 400 g/kg wheat straw respectively (on an air dry base). It was then ensiled at ambient temperature in airtight plastic containers for six weeks. These conditions approximate optimum conditions for the ammoniation of wheat straw by an aqueous urea solution (Kritzinger & Franck, 1981).

After six weeks the bags were opened and the contents

spread on a wooden floor to dry. When the treated straw reached the required moisture level of approximately 10 percent, four experimental diets were formulated as represented in Table 1.

These diets were each fed to five adult SA Mutton Merino wethers in an intake and *in vivo* digestibility trial over a period of 35 days. The wethers were stratified randomly according to a 2 × 2 factorial design. During the collection period of seven days, the sheep were fed at a level of 15% below voluntary intake. Afterwards, representative samples of the experimental diets and the faeces and urine of individual sheep were taken and analysed according to the methods of the A.O.A.C. (1970) for organic matter (OM), crude protein (CP) and crude fibre (CF). The fibre fractions were analysed by methods described by Van Soest (1963) and Van Soest & Wine (1967). The apparent digestibility coefficients of OM, CP, CF, acid detergent fibre (ADF), cell wall constituents (CWC) and hemicellulose, as well as the nitrogen retention (N-retention), were calculated. Voluntary intake and digestible OM and CP intake per metabolic mass ($W^{0,75}$) were also calculated. Results were analysed according to standard procedures for a factorial design (Snedecor & Cochran, 1967).

**Table 1** Formulation of the experimental diets (percentages on a natural basis)

| | Untreated | | Ammoniated | |
|---|---|---|---|---|
| Component | 9% CP | 13% CP | 9% CP | 13% CP |
| Untreated wheat straw* | 94 | 89 | — | — |
| Ammoniated wheat straw | — | — | 94 | 89 |
| Molasses meal | 6 | 6 | 6 | 6 |
| Fish meal | — | 5 | — | 5 |

*Urea was used to adjust the protein content of the untreated straw to that of the ammioniated straw.

**Table 2** Chemical composition of the experimental diets (DM-basis)

| | Untreated | | Ammoniated | |
|---|---|---|---|---|
| Fraction (%) | 9% CP | 13% CP | 9% CP | 13% CP |
| DM | 90,8 | 90,3 | 89,6 | 89,4 |
| OM | 94,2 | 94,0 | 93,7 | 93,0 |
| CP | 8,8 | 13,2 | 9,1 | 13,2 |
| CF | 34,7 | 35,2 | 36,9 | 35,1 |
| ADF | 38,9 | 36,8 | 39,3 | 37,6 |
| CWC | 72,6 | 70,2 | 70,4 | 67,8 |
| Hemicellulose | 33,6 | 33,4 | 31,0 | 30,1 |

## Results and Discussion

### Chemical composition

The chemical composition of the experimental diets is presented in Table 2. From Table 2 it is evident that the DM, OM and CF contents of the experimental diets were relatively stable. CP was raised from 9 to 13% by the inclusion of fish meal. ADF seemed to increase slightly due to ammoniation. CWC and hemicellulose decreased approximately 2,5 percentage units due to ammoniation. This observation is in agreement with results obtained by Horton (1981). Kiangi & Kategile (1981) also reported a decrease in CWC of maize stover ammoniated by urea. ADF, CWC and hemicellulose, to a lesser extent, seemed to decrease slightly due to the inclusion of fish meal in the experimental diets.

It should be mentioned that the CP-content of ammoniated straw was approximately 9%, compared to a CP-content of 5,02% determined in untreated straw. As previously mentioned, urea was used to adjust the CP-content of the untreated diets to that of the ammoniated diets, in order to present the diets on an isonitrogenous basis.

### Voluntary intake

The voluntary intake per $W^{0,75}$ obtained is presented in Table 3. Ammoniation significantly ($P \leq 0,01$) improved voluntary intake by 27,3% (Table 3). No change due to protein level was observed. The improvement in voluntary intake due to ammoniation is in agreement with reports in the literature. Anhydrous ammoniation resulted in improvements in voluntary intake of 45, 70 and 11,5%, as reported by Oji, Mowat & Winch (1977), Lawlor & O'Shea (1979) and Morris & Mowat (1980) for maize stover, wheat straw and maize stover respectively. Hadjipanayiotou (1982) obtained a corresponding figure of 47% for barley straw ammoniated by urea. Dolberg, Saadullah, Haque & Ahmed (1981) reported intake results quite similar to those obtained in the present study after ammoniation of rice straw by urea.

### Apparent digestibility

Apparent digestibility coefficients for OM, CP, CF, ADF, CWC and hemicellulose are presented in Table 4. Both indirect ammoniation and the higher protein level of 13% CP significantly ($P \leq 0,05$) improved the apparent digestibility of OM by 7,1 and 6,2% respectively (Table 4). The improvement in apparent digestibility of OM due

**Table 3** Voluntary intake per metabolic mass (gDM/$W^{0,75}$/day)

| | Untreated | | Ammoniated | | | % Change | |
|---|---|---|---|---|---|---|---|
| Voluntary intake | 9% CP | 13% CP | 9% CP | 13% CP | SE mean | Ammoniation | Protein level |
| gDM/$W^{0,75}$/day | 55,3 | 52,4 | 67,4 | 69,7 | 1,25 | 27,3** | $O^{NS}$ |

** Significant ($P \leq 0,01$). $^{NS}$ Not significant.

to ammoniation is consistent with results obtained by Garrett, Walker, Kohler & Hart (1979); Lawlor & O'Shea (1979); Morris & Mowat (1980) and Horton, Nicholson & Christensen (1982) for anhydrous ammonia treatments. It is also in agreement with results obtained by Dolberg, Saadullah, Haque & Ahmed, (1981) and Hadjipanayiotou (1982) for ammoniation by urea of rice and barley straw respectively. Corresponding figures of 9 and 26% improvement in the apparent digestibility of OM were published by Morris & Mowat (1980) for maize stover and Hadjipanayiotou (1982) for barley straw respectively.

The apparent digestibility of CP was significantly ($P \leq 0,01$) reduced by 25,3% due to ammoniation, while it was significantly ($P \leq 0,01$) improved by 30,6% at the higher protein level (Table 4). The reduction in protein digestibility of wheat straw ammoniated by urea confirmed a trend obtained in earlier work (Cloete & De Villiers, 1983). Reductions in protein digestibility have also been reported by Oji, Mowat & Winch (1977); Garret, Walker, Kohler & Hart (1979); Morris & Mowat (1980) and Horton, Nicholson & Christensen (1982) on maize stover, rice straw, maize stover and wheat straw respectively. However, none of these authors reported a reduction of the same magnitude as experienced in the present study. The reduction in protein digestibility seems to be related to colour-changes taking place during ammoniation of fibrous materials, as postulated by Scheurch & Davidson (1971, quoted by Oji, Mowat & Winch, 1977). According to these authors the colour-changes arise from oxidation of phenols, or the condensation of aldehydic fractions in sugars with a nitrogenous base (via the Maillard reaction), to a number of coloured products. Because of these relatively strong bonds the nitrogen may not be entirely available for utilization by the ruminal microbes. Furthermore, since ammoniation increased voluntary DM intake, more fibre could have reached the large intestine. This could possibly lead to some hindgut fermentation (Hoover, 1978) and the synthesis of microbial protein. As ammonia is more readily absorbed in the hindgut (Hoover, 1978), this microbial protein could partly account for the high level of fecal nitrogen observed on the ammoniated diets, resulting in a decrease of apparent digestibility of CP.

Ammoniation significantly ($P \leq 0,01$) increased the apparent digestibility of CF, CWC and hemicullulose by 14,8; 17,6 and 32,6 respectively. The apparent digestibility of ADF was not significantly improved, (4,3%.) Increases ranging from 4,1 to 6,5% were observed in the apparent digestibility of the various fibre fractions due to the higher protein level. Only the increase of 6,5% in CF digestibility reached statistical significance ($P \leq 0,05$). The increase in the apparent digestibility of the different fibre fractions due to ammoniation, is consistent with reports in the literature. Comparable increases in fibre digestibility are reported by Oji, Mowat & Winch (1977); Oji & Mowat (1979); Morris & Mowat (1980) and Horton, Nicholson & Christensen (1982). The latter authors reported on wheat straw, while the other authors worked on maize stover. The improvement in the apparent digestibility of ADF obtained in the present study is somewhat smaller than comparable results in the literature.

## Digestible nutrient intake and N-retention

The digestible OM and CP intake per $W^{0,75}$ obtained during the collection period of the digestibility trial and N-retention are presented in Table 5. From Table 5 it is evident that ammoniation significantly ($P \leq 0,01$) improved the digestible OM intake per day by 36,3%. This marked increase was brought about by an increase of 27,3% in voluntary intake and an increase of 7,1% in the apparent digestibility of OM. The improvement of the digestible OM intake of 5,4% at the higher CP level was not significant. The reduced CP digestibility was cancelled by the higher voluntary intake observed on the ammoniated diets. As a result, ammoniation did not significantly affect digestible CP intake. The higher CP level markedly increased digestible CP intake per day by 91,3%.

Ammoniation significantly ($P \leq 0,01$) reduced N-retention by 38,6%, due to a significant ($P \leq 0,01$) increase of 63,1% in total nitrogen excretion. The main factor contributing to this result was a marked increase of 87,2% in fecal nitrogen. The authors are not aware of results in the literature which support this observation. Morris & Mowat (1980) obtained negative N-retention values on ammoniated maize stover. This observation can be explained by the low energy content of the rations, resulting in the utilization of protein to fulfil the energy requirements of the experimental animals. N-retention was still slightly improved by ammoniation. Oji & Mowat (1979) and Hadjipanayiotou (1982) obtained slight, non-significant, improvements in N-retention on ammoniated diets.

**Table 4** Apparent digestibility coefficients (percentages on a DM-basis)

| | Untreated | | Ammoniated | | | % Change | |
|---|---|---|---|---|---|---|---|
| Fraction | 9% CP | 13% CP | 9% CP | 13% CP | SE mean | Ammoniation | Protein level |
| OM | 52,7 | 57,0 | 57,5 | 60,0 | 0,46 | 7,1* | 6,2* |
| CP | 58,6 | 71,6 | 40,0 | 57,2 | 0,83 | −25,3** | 30,6** |
| CF | 57,3 | 63,8 | 68,7 | 70,3 | 0,78 | 14,8** | 6,5* |
| ADF | 50,0 | 52,5 | 52,3 | 54,6 | 1,14 | $4,3^{NS}$ | $4,7^{NS}$ |
| CWC | 53,1 | 57,9 | 64,5 | 66,0 | 0,83 | 17,6** | $5,4^{NS}$ |
| Hemicellulose | 58,0 | 63,1 | 80,1 | 80,5 | 0,79 | 32,6** | $4,1^{NS}$ |

* Significant ($P \leq 0,05$). ** Significant ($P \leq 0,01$). $^{NS}$ Not significant.

**Table 5** The digestible nutrient intake per $W^{0,75}$ and N-retention (g/day)

| Nutrient intake and N-retention | Untreated | | Ammoniated | | SE mean | % Change | |
|---|---|---|---|---|---|---|---|
| | 9% CP | 13% CP | 9% CP | 13% CP | | Ammoniation | Protein level |
| gDOM intake/$W^{0,75}$/day | 23,0 | 23,7 | 30,8 | 33,0 | 0,55 | 36,3** | $5,4^{NS}$ |
| gDCP intake/$W^{0,75}$/day | 2,4 | 4,2 | 2,1 | 4,5 | 0,07 | $0^{NS}$ | 91,3** |
| gN retained/day | 7,0 | 8,8 | 3,0 | 6,7 | 0,40 | −38,6** | 55,0** |

** Significant ($P \leq 0,01$) $^{NS}$ Not significant.

## Conclusions

Ammoniation by urea seems to be a practical way of improving the nutritive value of low quality roughages. Voluntary intake and apparent digestibility of OM were significantly improved by ammoniation, resulting in a marked increase in the daily digestible OM intake per $W^{0,75}$. The apparent digestibility of the various fibre fractions was also improved.

Ammoniation considerably reduced the apparent digestibility of CP. N-retention followed the same trend, mainly because of higher fecal nitrogen levels obtained on the ammoniated diets. Despite the decrease in protein digestibility and N-retention, ammoniation by urea seems to be a promising technique.

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