# Effect of supplementation on the digestibility of roughage diets

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Supplementation of low quality Mongolian hay and barley straw with urea, minerals and a small quantity (11 – 14% of total DM) of easily digestible carbohydrate had a positive influence on *in vivo* digestibility, increasing the net energy value of the low quality roughages by up to 34%. The rumen ammonia concentration was maintained above the critical level by the recycling of N to the rumen. Supplementation with a concentrate increased the retention time of hay in the digestive tract when compared with feeding hay alone. NaOH-treatment of barley straw increased the digestibility and rate of passage through the digestive tract.

Aanvulling van lae kwaliteit Mongoolse hooi en rogstrooi met ureum, minerale en 'n klein hoeveelheid (11 – 14% van totale DM) maklik verteerbare koolhidrate, het 'n positiewe invloed gehad op die *in vivo* verteerbaarheid en die totale energiewaarde van lae kwaliteit ruvoere is verhoog met tot 34%. Die ammoniakkonsentrasie van die grootpens is bokant die kritieke vlak gehandhaaf deur die hersirkulasie van N na die grootpens. In vergelyking met die voer van hooi alleen het die aanvulling met koolhidrate die retensietyd van hooi in die verteringskanaal verleng. Die behandeling van rogstrooi met NaOH het die verteerbaarheid sowel as die tempo van deurvloei deur die verteringskanaal verhoog.

**Keywords:** Supplementation, digestibility, rate of passage, nitrogen, minerals, easily degradable carbohydrates

## Introduction

One of the reasons for the low digestibility of the poor quality roughages is its failure to provide the rumen microorganisms with all their nutrient requirements. Digestibility and intake can be improved by proper supplementation.

The purpose of this study was to highlight the effect of urea, macro- and micro-elements, barley, wheat bran and molasses supplementation of poor quality hay and barley straw on digestion by sheep.

## Materials and Methods

Three metabolism trials were conducted with wethers to study the effect of supplementation on digestibility and rumen fermentation parameters of low quality Mongolian hay (exp. I), ground and pelleted barley straw (exp. II) and the same straw treated with NaOH (exp. III). The composition of the hay and barley are given in Table 1. Each roughage was tested as follows:

(a) without supplements except 7 g NaCl/day (diet 1)
(b) with urea (diet 2)
(c) with urea + minerals (diet 3 and 3a)
(d) with urea + minerals + EDC (diet 4)

The easily degradable carbohydrate (EDC) supplement consisted of 50 g barley + 50 g wheat bran in exp. I, 140 g molasses in exp. II and 200 g molasses in exp. III, and formed 11 – 14% of the DM of total rations (Table 2). Rations were evaluated at 90% of the *ad lib.* intake determined during the 14-d preliminary period. The collection period lasted 10 d after allowing 5 d to adjust to the level of feeding. Each diet was fed to 3 wethers twice daily. Improved Mongolian Sheep (22 – 27 kg livemass) were used in exp. I and Trace Merino Sheep (55 – 63 kg livemass) were used in exp. II and III. Digestibility coefficients for diet 4 were calculated using DM digestibility values of 78% for barley, 62% for wheat bran and 94% for molasses, obtained from the literature.

**Table 1** Composition of Mongolian hay and barley straw used in the experiments

| Component | Mongolian hay | Barley straw |
|---|---|---|
| | (g/kg DM) | (g/kg DM) |
| Crude protein | 66,5 | 44,8 |
| Crude fibre | 378,3 | 442,0 |
| Ca | 7,2 | 3,5 |
| P | 2,0 | 1,0 |
| Mg | 1,6 | 0,8 |
| S | 1,2 | 1,8 |
| Na[a] | 4,1 | 3,5 |
| Cl[a] | 9,2 | 8,5 |
| K | 15,8 | 13,9 |
| | (mg/kg DM) | (mg/kg DM) |
| Fe | 208 | 129 |
| Cu | 5,9 | 3,0 |
| Zn | 30 | 35 |
| Mn | 69 | 37 |
| Co | 0,01 | 0,08 |
| I | 0,05 | 0,05 |

[a]Includes NaCl supplement

**Table 2** Dry matter intake and crude protein (N × 6,25) content of experimental diets

| | Experiment | | |
|---|---|---|---|
| Diets | I hay (0,75 kg/d) | II straw (0,7 kg/d) | III NaOH-treated straw (1,0 kg/d) |
| Dry matter intake (g/kg $W^{0,75}$) | | | |
| 1. Without supplements | 66 | 31 | 43 |
| 2. + Urea | 60 | – | – |
| 3. + Urea + minerals[a] | 64 | 29 | 42 |
| 3a. + Urea + minerals[a] | – | 30 | 43 |
| 4. + Urea + minerals + EDC[b] | 71 | 34 | 48 |
| Crude protein (% of DM) | | | |
| 1. Without supplements | 6,7 | 4,5 | 4,4 |
| 2. + Urea | 13,0 | – | – |
| 3. + Urea + minerals[a] | 12,6<br>12,6 | 8,9<br>8,9 | 8,9<br>8,9 |
| 3a. + Urea + minerals[a] | – | 12,1 | 12,1 |
| 4. + Urea + minerals + EDC[b] | 13,4 | 12,1 | 12,1 |

[a]Per kilogram roughage 2,1 g Ca, 1,5 g P, 0,8 g Mg, 1 g S, 40 mg Fe, 7 mg Cu, 30 mg Mn, 30 mg Zn, 0,7 mg Co and 0,36 mg I
[b]EDC = easily degradable carbohydrates (see text)

The rate of passage of food through the digestive tract was measured with coloured hay and straw. Rumen liquid pH was measured with a glass electrode and pH-meter, total

volatile fatty acids (TVFA) by distillation with a Markham apparatus, and ammonia by microdiffusion analysis. Rumen content was taken from rumen fistulated wethers fed experimental diets before feeding and 1, 3, 5 and 8 h after feeding. Cellulolytic activity of rumen contents was measured by inserting cellulose (cotton thread) in the rumen of fistulated sheep for 48 h. The difference in the weight before and after incubation was expressed as a % of original weight of cellulose.

## Results and Discussion

All the supplements — urea, minerals and EDC — showed a tendency to increase the digestibility of roughage DM. In exp. I the digestibility of hay + urea + minerals + barley + wheat bran was significantly higher than non supplemented hay (Table 3). Cellulolytic activity of rumen content for wethers fed hay only (11,8 ± 0,93%) increased to 22,3 ± 0,92% for wethers fed hay + urea + minerals. TVFA concentration in rumen content increased slightly after a urea + minerals supplementation of low quality hay (35,8 vs. 29,9 mM). There was no significant difference in pH-values (7,18 vs. 7,17). The ammonia concentration increased 2 – 3 times compared with non supplemented rations (Table 4). The estimated net energy value of hay expressed as starch equivalents increased by 23% on addition of urea, by 30% for hay + urea + minerals and by 34% for hay + urea + minerals + EDC.

**Table 3** Dry matter digestibility of roughages and retention time of food in the digestive tract on experimental diets

| Diets | Experiments I Hay | II Straw | III NaOH-treated straw |
|---|---|---|---|
| DM digestibility (%) | | | |
| 1. Without supplements | 42,4$^{a}$ | 44,7$^{a}$ | 51,2$^{b}$ |
| 2. + Urea | 46,2$^{ab}$ | – | – |
| 3. + Urea + minerals | 48,0$^{bc}$ | 45,5$^{ac}$ | 53,3$^{b}$ |
| 3a. + Urea + minerals | – | 45,5$^{a}$ | 54,9$^{b}$ |
| 4. + Urea + minerals + EDC* | 50,0$^{bc}$ | 46,2$^{ac}$ | 52,8$^{b}$ |
| Retention time (h) | | | |
| 1. Without supplements | 67$^{ac}$ | 74$^{bc}$ | 68$^{ab}$ |
| 2. + Urea | 69$^{ab}$ | – | – |
| 3. + Urea + minerals | 70$^{ab}$ | 71$^{bc}$ | 62$^{a}$ |
| 3a. + Urea + minerals | – | 72$^{bc}$ | 60$^{a}$ |
| 4. + Urea + minerals + EDC* | 74$^{b}$ | 70$^{cd}$ | 61$^{ad}$ |

*EDC = easily degradable carbohydrates. Data given are only for roughage digestibility

$^{abcd}$ = values with the same letter do not differ significantly ($P<0,05$)

The barley straw diet had a level of crude protein which increased from 4,4 to 9 or 12% of DM with minerals and EDC supplementation (Table 2). One of the reasons for the small difference in digestibility (Table 3) is probably that ammonia concentration in the rumen never fell below 30 mg/l even when non supplemented roughages were fed (Table 4). It seems that the recycling of nitrogen to the rumen and hind gut was sufficient to keep ammonia in the digestive tract above the critical level for microbial digestion. When the EDC content of forage is as low as that in straw and the intake is very low (under 45 g/kg $W^{0,75}$), the limiting factor for the rumen bacterial growth is not nitrogen. The effect of the nitrogen level on microbial digestibility in rumen increased with increasing intake and EDC in the ration, as is evident if it is compared with data from exp. III with barley straw, and exp. I with hay (Table 3).

**Table 4** Ammonia concentration in the rumen liquid (mg/l) on experimental diets[a]*

| Diets | Time after feeding (h) 0 | 1 | 3 | 5 | 8 | Mean |
|---|---|---|---|---|---|---|
| Experiment I | | | | | | |
| 1. Hay | 44 | 60 | 92 | 65 | 63 | 65 |
| 3. Hay + urea + minerals | 77 | 125 | 120 | 91 | 98 | 102 |
| Experiment II | | | | | | |
| 1. Straw | 31 | 30 | 43 | 41 | 30 | 35 |
| 3a. Straw + urea + minerals | 70 | 141 | 108 | 81 | 51 | 90 |

[a]Differences between the two rations in each experiment were significant statistically ($P<0,05$)

Treatment with NaOH increased the digestibility of barley straw. The difference between treated and non treated straw is statistically significant when urea + minerals were added to the straw (diets 3 and 3a).

The rate of passage of food through the digestive tract did not change significantly when urea, minerals or a small quantity of molasses were added to the roughages. Combined supplementation of hay with urea + minerals + ground barley + wheat bran increased the retention time of food particles in the digestive tract compared with non supplemented hay. Treatment of straw with NaOH increased the rate of passage of the ingesta (Table 3). Treatment also increased the dry matter intake per kilogram metabolic weight by approximately 42% (Table 2).

In conclusion, supplementation of low quality hay and straw with nitrogen (urea), minerals and a small quantity of readily available carbohydrate has a positive influence on *in vivo* digestibility by sheep. By correct supplementation the estimated net energy value of low quality hay can be increased by up to 34%. It seems that nitrogen is most important since at a very low level of intake it is possible to maintain a critical concentration of rumen ammonia owing to the recycling of nitrogen between body and rumen pools. The effect of the nitrogen level on digestibility

depends on the level of intake and the composition of the ration. The combination of hay and concentrate in the ration of sheep increased the retention time of hay in the digestive tract, when compared with feeding hay alone. NaOH treatment of straw increased digestibility and the rate of passage of the straw through the digestive tract.