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Effect of sodium-hydroxide treatment on ruminal starch degradability of wheat and milk production of dairy cows

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SUMMARY

Two, an *in situ* and a field, trials were performed for the investigation of the effects of sodium-hydroxide treatment on ruminal degradability of wheat grain nutrient content and its effect on milk production and milk composition.

The effect of sodium-hydroxide treatment (NaOH) in the concentration of 3% on ruminal starch and dry matter degradability of wheat was investigated using the *in situ* (in sacco) method. The NaOH treatment significantly decreased dry matter and starch degradability of wheat in the rumen.

A trial was carried out to investigate the effect of feeding wheat grain treated with 3% NaOH (*Sodagrain*) to dairy cows on milk production and milk composition. During the experiment, cows were fed 2 kg/day treated (with 3% NaOH, whole grain) and untreated (ground) wheat. It was found, that feeding *Sodagrain* significantly increased milk yield, solids-non fat and protein content of the milk compared to the ground wheat.

Keywords: dairy cows, sodium-hydroxide, sodium-hydroxide treated wheat grain, milk production, milk composition.

INTRODUCTION

The high yielding dairy cow requires a great amount of glucose mainly to synthesize lactose, and for the synthesis of milk fat (to produce NADP + H^+ *via* pentose phosphate pathway) and to maintain the nervous system as well. Dairy cows producing 30–50 kg milk per day require approximately 2.5–4.0 kg glucose daily, but only a small amount (0.5–1.0 kg/day) of glucose is absorbed in the small intestine (*Flachowsky* and *Lebzien* 1997). Blood plasma and liver glucose pool in the cow limited to 520–550 g, thus 1.0–3.0 kg glucose has to be synthesized through the gluconeogenesis pathway for the milk production mentioned.

Besides improving gluconeogenesis, increasing the grain content of the diet is often used in practice. However, feeding high grain diets with high rumen degradable starch content decrease rumen pH, dry matter intake, and modify the population of rumen micro-organisms. Moreover, these diets increase rumen propionate concentration, and therefore decrease the acetate to propionate ratio and fibre digestion and increase the incidence of rumen acidosis. It is well known that from the point of energy utilization, enzymatic digestion of starch in the small intestine is more efficient than microbial fermentation in the rumen and large intestine (*Leng* 1981, *Owens et al.* 1986, *McDonald et al.* 1995, *Boss* and *Bowman* 1996, *Huntington* 1997, *Lebzien et al.* 2002). Starch degradation in the small intestine produces 33–42% more net energy in comparison with the microbial degradation of starch in the rumen (*Owens et al.* 1986, *Merchen et al.* 1997).

It is also known, that the ruminal degradation of starch can be altered by physical methods and chemical treatments. The physical methods (e.g. grinding, flaking) usually increase both ruminal and small intestinal starch degradations. On the other hand, the chemical treatments of different grains with sodium-hydroxide (NaOH, *Lebzien et al.* 1996), ammonia (*Robinson* and *Kennelly* 1988, 1989, *Okine* and *Kennelly* 1994), and formaldehyde (*Fluharty* and *Loerch* 1989, *McAllister et al.* 1990) were able to decrease the degradation of starch in the rumen, and therefore increase the amount of starch passing to the small intestine (*Phipps et al.* 2001). In contrast, *Ortega-Cerilla et al.* (1999) found that formaldehyde treatment did not increase the amount of starch entering the small intestine. Likewise, treating grains with glioxal, propane-aldehyde, and tannine were found to be ineffective (*Okine* and *Kennelly* 1994).

Earlier *in situ* studies (*Tóth* and *Schmidt* 2003, 2004) indicated that the treatments of wheat by 2% NaOH (as fed basis) resulted in a decreased ruminal dry matter (DM) digestibility and increased the amount of bypass starch. We have also found (*Schmidt et al.* 2006) that feeding 2 kg/day wheat treated with sodium-hydroxide (NaOH) did not affect negatively the main parameters of rumen fermentation (e.g. pH, VFA-content, microbial activity). Fiber degradation was significantly improved, but starch and protein degradation was lower in the rumen when NaOH-treated wheat was fed. The *in vivo* experiments demonstrated that feeding NaOH-treated wheat to steers significantly increased the amount of starch that reached the small intestine. This improved quantity of starch was digested and absorbed, which can provide an increased glucose supply to the animals.

In the present experiment using *in situ* method and rumen canulated steers was performed to investigate the effect of sodium-hydroxide treatments on ruminal dry matter and starch degradability of wheat grain. Moreover, a field trial was carried out to investigate the effect of feeding daily 2 kg wheat grain treated with 3% NaOH (*Sodagrain*) to dairy cows on milk production and milk composition.

Materials and Methods

The *in situ* experiment was performed using 4 rumen cannulated *Holstein Friesian* steers. The bags were made from Scrynel plastic (*Zürcher Beuteltuchfabrick AG., Switzerland*)

with the pore size of 40 μm, 2 g of wheat grains were dosed per bag, thus the volume of material per 1 cm^2 of the surface of the bag was 13.9 mg. The incubation periods were 24 hours in all cases, and the measurements were done in 3 replications.

A field trial (*Solum Co., Komárom, Hungary*) was carried out to investigate the effect of feeding wheat grain treated with 3% NaOH (Sodagrain) to dairy cows on milk production and milk composition. A total of 46 crossbred Holstein cows (R3, at the 2nd period of their lactation) were used, 23 cows in both the control and the experimental groups. Effort was made to form similar control and experimental groups in milk production and other parameters (*Table 1.*).

Table 1. Parameters in the field trial that were used for selecting the control and treatment cows

	Control	**Experimental**
	group	
Number of cows in the control and experimental group	23	23
Average milk production in the previous lactation (l)	9141.2	9144.0
Lactation number (so far)	2.4	2.4
Days after parturition	100	101
Average daily milk production (l/cow)*	34.3	34.3

*During a two week period before the beginning of the trial

Table 2. shows the ingredient composition and nutrient content of the daily feed ration. The control and experimental cows consumed 2 kg/day ground wheat or 3% NaOH treated wheat, respectively. We did the treatment of the wheat with 3% NaOH using a *Keenan*-formed mixing-reeled feedmixer and carriage car. We spread over the treated feed in about 50 cm high coating and we started to feed this after the 4^{th} day of the treatment. The wheat grain after the treatment becomes softer and it gets smeared consistency. We reduced to half of the buffer (sodium bicarbonate based product) in the daily ration of the experimental group because with the NaOH treatment we got considerable Na^+ in the rumen to improve the pH.

Cows were milked twice daily (morning and evening), and milk samples were taken from both the morning and the evening milk for 2 days a week for the chemical analysis. Milk samples from the morning and evening milking were pooled in relation to the previous milk yield records.

The composition of milk was analyzed by the *Hungarian Dairy Research Institute* (Mosonmagyaróvár, Hungary), where the fat, protein, lactose, dry matter and solids-non fat contents of the milk were measured. Milkoscan FT 120 (*Foss Electric*) equipment was used for the analysis.

The chemical content of the feeds were analyzed according to the *Hungarian Feed Codex* (1990). Starch content of feed was measured with a polarimeter (*Carl Zeiss, Jena, Germany*) as described in the *Hungarian Feed Codex* (1990).

Data were analyzed using the t-test procedure of *STATISTICA 6.0.* program.

Table 2. Composition and measured nutrient content of daily feed ration

Ingredient and/or nutrient	Control group	Experimental group
	kg/cow/day	
Corn silage	15.8	15.8
Potato	10.3	10.3
Alfalfa haylage	5.0	5.0
Corn	3.2	3.2
Wheat	2.0	–
Sodium-hydroxide treated wheat	–	2.0
Extracted sunflower meal (38% CP)	2.3	2.3
Alfalfa hay	1.6	1.6
Grass hay	2.0	2.0
Protavit Minor (concentrate)*	1.3	1.3
Magalac (Ca-soap)	0.3	0.3
KSZP-961 (premix)*	0.3	0.3
Bio-Boost (yeast and organic ultra trace elements)**	0.2	0.2
Buffer (sodium bicarbonate)*	0.1	0.05
SUM (kg)	44.4	44.3
Nutrient content of daily feed ration		
Dry matter (kg)	20.88	20.84
Net energy for lactation (NE_l) MJ	141.54	141.54
NE_l, MJ/kg DM	6.78	6.79
Energy dependent metabolizable protein (g)	2177	2177
N dependent metabolizable protein (g)	2234	2334
Crude protein (g)	3443	3444
Crude protein (% of DM)	16.5	16.5
Bypass protein (% of crude protein)	35.8	35.8
Crude fibre (g)	3480	3480
Crude fibre (% of DM)	16.6	16.7
Crude fat (g)	686.6	686.6
Calcium (g)	203	198
Phosphorus (g)	95	95

*produced by Bábolna Feed Ltd., **produced by Alltech Hungary Ltd.

Results

Table 3. summarizes the results of the *in situ* experiment. We found that the treatment of wheat grain with 3% NaOH significantly ($P < 0.001$) decreased the degradabilty of the dry matter in the rumen as compared to the untreated wheat. The results of our previous trials (*Tóth* and *Schmidt* 2003, 2004) and the present study indicate that the NaOH treatment

of whole wheat decreased the dry matter degradation in the rumen to a greater extent as compared to the caustic soda treated ground wheat. The reason for this observation is likely the different physical form (whole wheat grain *vs.* ground wheat). Therefore, the treatment of whole grain is recommended for the practice because the cost associated with the grinding can be saved.

Table 3. Effect of NaOH treatment on ruminal dry matter degradability and bypass starch content of wheat (Incubation time: 24 hours)

	Ground wheat (control)	**NaOH-treated wheat grain**
Dry matter degradation[1] (%)	91.0±2.1	76.3±8.5***
Bypass starch[2] (%)	2.1±0.9	20.6±7.6***

Difference within a row: *** $P < 0.001$ [1] % of feed, [2] % of starch content

The data on dry matter degradation indicate that the NaOH treatment significantly ($P < 0.001$) improved (from 2.1% to 20.6%) the amount of the bypass strach in comparison to the ground wheat.

The treatment of wheat with NaOH is called Sodagrain in the practice, and it is more beneficial in those countries, where the farmers can use more wheat in the feed ration for dairy cows, like in Germany and Ireland. Although it is widely used in the practice, there is not much scientific experiments and results in this subject. According to scientific literature, the NaOH treatment in a higher dosage did not have negative effect on the health of the animals (*Daenicke* and *Lebzien* 1995), and this treatment might help in the prevention of acidosis because of the basic effect of NaOH (*Demeterova* and *Vajda* 2000). Furthermore, in these studies it was reported that the milk production and the composition of the milk did not change.

In present experiment, however, the feeding of the caustic soda treated wheat to the cows significantly improved milk production and the amount of milk protein as compared to the control group (*Table 4.*), but we should not overrate the accretion in the milk protein (+0.07%). The significant ($P < 0.05$) increase in non-fat-solids was primary the result of the increased milk protein concentration.

Table 4. Daily milk production and milk composition of the control and experimental groups

	Control group	**Experimental group**
Milk production (kg/day)	31.94±4.8	33.03±4.0***
Milk composition % (w/w)		
Milk fat (%)	3.78±0.42	3.78±0.54
Milk protein (%)	3.38±0.27	3.45±0.25*
Lactose (%)	4.74±0.17	4.75±0.18
Dry matter (%)	12.72±0.73	12.71±0.78
Solids-non-fat (%)	8.94±0.37	8.93±0.33*

Difference within a row: *** $P < 0.001$, * $P < 0.05$

The results suggest that the reason of the improved milk yield could correlate with the NaOH treatment: the cows can use more glucose for the lactogenesis as a result of the lower starch degradability of the treated wheat in the rumen. The increase in the milk protein can also be the result of the better glucose supply. Presumably, the cows used less amount of glucogenetic amino-acid for gluconeogenesis as well.

Conclusions

The results of the *in situ* experiment indicated that treating the wheat grain with 3% NaOH significantly decreased the degradability of the starch in the rumen, and therefore, the amount of the bypass starch increased as compared to the untreated ground wheat. In the feeding experiment, the NaOH-treatment of whole wheat significantly improved the milk production, protein and non-fat-solids content of milk as compared to the control (untreated ground wheat). However, feeding *Sodagrain* had no effect on the daily production of milk nutrients. Because of its simplicity and positive effect on milk production, the NaOH treatment of wheat grain can be suggested for the practice, specially where the farmers use more wheat in the feed ration for dairy cows.

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A NaOH-dal végzett kezelés hatása a búza keményítőjének bendőbeli lebonthatóságára és a tehenek tejtermelésére

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Összefoglalás

A szerzők 4 bendőkanüllel ellátott tinóval, *in situ* technikával végzett kísérletben, a 3% NaOH-dal végzett kezelés hatását vizsgálták a búza szárazanyagának, illetve keményítőjének bendőbeli lebonthatóságára. A nátronlúgos kezelés szignifikánsan csökkentette a szárazanyag és a keményítő bendőbeli lebonthatóságát.

Az elvégzett üzemi kísérletben a tehenenként napi 2 kg-os adagban etetett, 3% NaOH-dal kezelt egész szemű búza a kezeletlen búzadarához képest szignifikánsan növelte a tehenek tejtermelését, illetve a tej fehérje, valamint zsírmentes szárazanyag-tartalmát, míg a kezelés a többi vizsgált paramétert (tejzsír, tejcukor, szárazanyag) nem befolyásolta szignifikáns mértékben.
Kulcsszavak: tejelő tehén, NaOH, nátrium-hidroxiddal kezelt búza, tejtermelés, tejösszetétel.

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