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EFFECT OF GROUND AND CRASHED WHEAT FEEDING ON RUMINAL STARCH DEGRADATION AND PASSAGE OF AMINO ACIDS INTO THE DUODENUM

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Four non lactating cows with rumen and duodenal T-cannules were used in the 2 x 2 Latin square experiment to study the effect of crushed and ground wheat grain on ruminal fermentaion on starch and amino acids outflow from the rumen. Cows were fed diets consisting of 70 % forage, 29 % wheat grain crushed (CW) or ground (GW), and 1 % VitamixS on dry matter basis. Chromic oxide was used as a marker of nutrient flow to the duodenum. The differences in pH, molar proportion of VFA. acetat:propionat ratio and ammonia–N concentration between crushed and ground wheat were not significant. Proccesing of wheat did not affect starch digestion in the rumen, in comparison with corn grain.The flow of crude protein and amino acids from the rumen was higher than their intake, except flow of total amino acids with ground wheat.

Key words: *wheat starch, grain processing, in sacco degradation, rumen fermentation, amino acids*

Carbohydrates of grains and forages are an important source of energy for ruminants. Since grains contain high leveles of starch, they influence the efficiency of using whole feeding ration in ruminants (Tamminga et al., 1990). There are considerable differences in the ruminal degradation of starch and crude protein from grains, maize, and other concentrates (Zebrowska et al., 1997). The rate and site of starch digestion are important in terms of nutrient availability in ruminants (Offner and Sauvant, 2004). The rate and extent of starch digestion in the rumen are affected by the structure of starch in the individual grain types (French, 1973; Kotarski et al., 1992). Maize starch is less degradable in the rumen than wheat, barley or oat starch. Up to 40 % of maize starch can be found to escape ruminal fermentation (Lebzien et al., 1997; Kotarski et al.,1992), while oats, barley or wheat starch are fermented in the rumen at least by 90 % (Ørskov, 1986). The proportion of starch escaping rumen digestion can be altered by changing the source of starch or grain procesing method. Physical processing of grain can effect utilization of starch by ruminants. It would be appear that progress had been made in grain preparation when simple grinding was replaced by crushing or dry rolling. Result of these processing methods are larger particles than after grinding and particle size influences rate, extent and site of cereal starch digestion.

The quantity of starch digested in the rumen and/or in the intestine has been discussed by many authors (Nocek and Tamminga. 1991; Mills et al., 1999a, b; Matthe, 2001; Kowalik et al., 2004; Čerešňáková et al., 2005). Processes of starch and crude protein degradation and fermentation in the rumen supplies the microbial proteosynthesis

with fermentable energy. For this reason synchronization of carbohydrate fermentation and release of nitrogen has great importance (Aldrich et al., 1993; Overton et al., 1998). On the extent of microbial proteosynthesis depends flow of microbial protein into the small intestinum and supplying of the animal with amino acids (Owens et al., 1986; Huntington, 1997; Čerešňáková et al., 2004 and others).

The aim of grain processing is to decrease starch degradation and fermentation in the rumen and increase the flow of starch into the duodenum where starch is the substrate used by ruminants for forming glucose by enzymatic digestion. Utilization efficiency of starch energy is more greater when starch is digested in the small intestine (Owens et al., 1986; Bergner and Hoffmann, 1997; Matthé, 2001).

Our investigation was focused on rumen fermentation and duodenal nutrients flow in nonlactating cows fed balanced diets that contained ground and crushed wheat**.** The technique *in sacco* was used for determination of ruminal starch degradability of crushed and ground wheat.

Four non lactating cows with a mean live weight of 550 kg were used in the experiment; the animals were fitted with large rumen fistulae and T-cannulae in the proximal duodenum. The cows were fed with the experimental diets twice a day. The diets contained 2.59 kg of dry matter of ground or crushed wheat. The amounts of the other components were balanced at 1.25 x maintenance ME requirements (Sommer et al., 1994). Water was always available.

The experimental design was replicated Latin square with 2 treatments. Chromic oxide was used as a marker of nutrient flow to the duodenum and apparent digestion of nutrients in the rumen. Preparation of Cr - marker and sampling of duodenal digesta was similar to those reported by Rohr et al. (1979). In the main experimental period the animals received daily 100 g of Cr_2O_3 marker in four portions (every six hours). Chromium content was 129.2 ± 0.3 mg in 1 g of Cr_2O_3 marker.

Wheat grain was processed in a crushing equipment Murska 350 S2 (Kemira, Finland) or in a hammer mill UH 50/18 (Germany). Feed consumption was recorded daily. Rests of feed were collected before morning feeding. The chemical composition of experimental feeds is given in table 1.

Table 1. ***Chemical composition (g/kg DM) of feeds in experimental diets***

Nutrients	Crushed wheat	Ground wheat	Maize silage	Lucerne hay
Dry matter (g/kg)	877.2	875.8	297.5	871.8
Crude protein	152.4	152.9	87.9	201.3
NDF	170.2	140.6	503.2	384.8
ADF	45.9	50.1	258.5	312.5
Hemicelluloses	130.3	90.6	240.2	72.4
Starch	626.6	646.3	283.3	52.3
Organic matter	975.7	977.3	958.4	905.2

In the sampling period (on d 1, 2, 3, and 4) duodenal samples were taken every 2 h to obtain a composite sample from 12 subsamples of a 24-h interval. Duodenal digesta samples were stored at - 20º C prior to analysis. The aliquots of the mean duodenal digesta samples were freeze-dried and used for Cr and nutrient determinations. Rumen fluid

was collected just before a.m. feeding (0 h) and 1, 3, 6 and 8 h after feeding on d 6 and 7 of the sampling period.

Effective degradation of wheat starch and degradation parameters (***a, b, c***) were determined by in sacco method (Harazim and Pavelek, 1999). Three rumen fistulated cows (fed twice a day by experimental diet consisting of 70 % forage and 30 % concentrate on dry matter basis) were used for 2, 3, 6, 9, 16, and 24 h of incubation time of crushed wheat and ground wheat samples (with a minimum of three bags per animal, incubation and feed). The parameters of starch degradation and effective degradation were calculated using the Neway progamme based on the equations described by Ørskov and McDonald (1979). In the calculation of effective starch degradation an outflow rate of 0.06 h^{-1} was used.

Chemical composition of feeds, rests of feeds, and duodenal freeze dried samples were determined by the Wende analysis (STN, 1977). Starch was determined by the enzymatic method according to Salomonsson et al. (1984). Concentration of Cr in duodenal samples was determined by AAS (Solar 9000 Unicam Cambridge, UK) according to the procedure of Williams et al. (1962). VFA concentration was determined using gas chromatography, ammonia concentration was measured by the Conway method.

The observations of in vivo experiment were evaluated by the analysis of variance with m observations (in one experiment m = 2) by the linear model (Gill. 1978):

$$y_{ijkl} = \mu + \rho_i + \gamma_j + \alpha_k + (\rho\gamma)_{ij} + e_{ijk}.$$

In the linear model y is the dependent variable, μ is the overall mean, ρ_i is the fixed effect of animals, γ_j is the fixed effect of period, α_k is the fixed effect of treatment. $(\rho\gamma)_{ij}$ is the fixed effect of interaction animal x period and e_{ijk} is the random residual effects distributed as N (0, σ^2). The significance of differences between periods or treatments were tested on the basis of F-test.

The effective degradability of starch in CM or GM and the parameters of degradation (a, b, c) were evaluated by using t-test.

Crushing compared with grinding decreased the effective in sacco degradation (Edg) of wheat starch by 6 % units ($P<0.05$) and crude protein by 7 % units (Table 2). Degradability was decreased significantly ($P<0.01$) but did not effected passage of starch to the duodenum in vivo (Table 4). Crushing of wheat had not so large effect on starch degradation like crushing of maize grain (Čerešňáková et al., 2005).

Table 2. ***Characteristics of wheat grain starch and crude protein degradation in the rumen***

Indices	Crushed wheat		Ground wheat	
	Starch	Crude protein	Starch	Crude protein
a. %	58.7	6.7^{A}	60.6	25.3^{B}
b. %	35.3	82.5^{A}	37.3	64.8^{B}
c. %.h^{-1}	0.400^{a}	0.188^{A}	0.433^{b}	0.235^{B}
Effective degradability. %	89.4^{a}	63.1^{A}	$93.4.5^{b}$	70.2^{B}

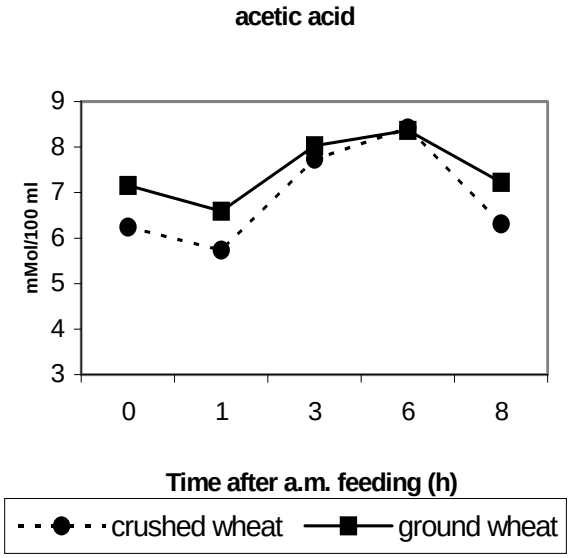
Within the row values with different superscripts (a : b and/or A : B) are significantly different ($P<0.01$).

In in vivo experiment the animals consumed slightly more the diet with crushed wheat than with ground wheat which resulted in higher starch intake (Table 3).

This difference did not affect ruminal fermentation processes. The total concentration of VFA was slightly higher with ground wheat which had higher degradability of starch also (Table 4). The mean molar proportion of VFA was similar with both diets, the differences for acetic acid and propionic acid were not significant. The changes of acetic and propionic acid with the time after feeding are illustrated in Fig. 2 and 3. The amount of wheat in the diets and its treatment did not effect pH value of ruminal fluid (Fig. 1). The similar tendency towards increased pH values and decreased VFA concentrations in the rumen fluid were observed by Lebzien and Rohr (1995) in experiment with crushed and ground wheat. Better effect on decreasing of starch ruminal degradability was attained by chemical treating of wheat (Lebzien et al., 1996). Decreasing of starch degradability is very important mainly in high concentrate diets composed of cereal grain (except maize grain) (Owens et al., 1986).

Table 3 **. *Mean daily intake of nutrients (g)***

Nutrients	Crushed wheat	Ground wheat
Dry matter	8896 ± 172	8878 ± 406
Crude protein	1346 ± 23	1242 ± 63
Fibre	1717 ± 14	1892 ± 35
NDF	3230 ± 48	3207 ± 115
ADF	1885 ± 25	1958 ± 48
Hemicellulose	1346 ± 24	1215 ± 54
Starch	2761 ± 62	2396 ± 180
Organic matter	8294± 157	8323 ± 375



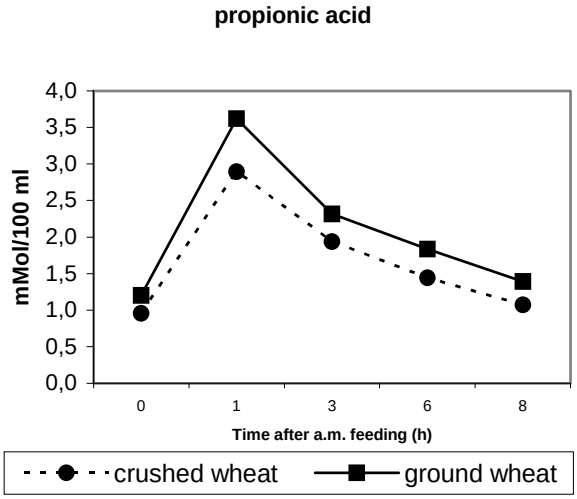


Figure 1 a 2. ***Changes of acetic and propionic acid concentrations in the rumen fluid***

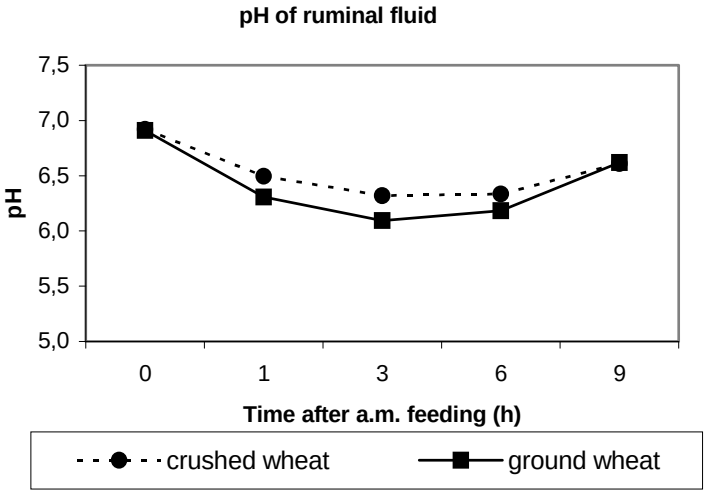


Figure 3. ***Rumen fluid pH on diets containing crushed and ground wheat***

*Table 4****. Effect of crushed or ground wheat on rumen fermentation products***

	Wheat		Signif. of differences
Indices	crushed	ground	
∑VFA (mM/100 ml)	10.4 ± 0.28	11.6 ± 0.36	**
VFA (mol %)			
Acetic acid	66.3 ± 1.99	65.1 ± 1.83	n.s.
Propionic acid	15.7 ± 1.53	17.5 ± 1.03	n.s.
Butyric acid	13.5 ± 0.49	13.2 ± 1.06	n.s.
Ammonia N (mg/100 ml)	15.6 ±0.98	16.3 ± 1.20	n.s.
pH	6.5 ± 0.10	6.4± 0.06	n.s.

** P <0.01; n.s. P>0.05

Starch passage to the duodenum was absolutely the same with crushed and/or ground wheat in the diet. Passage of starch to the duodenum was very low, 10.2 % (268 g/d resp., 257 g/d) of starch intake only (Table 5). Those data confirmed that crushing is not suitable treatment to reach higher passage of wheat starch from the rumen for effective utilisation of starch by animals (Owens et al., 1986; Matthé, 2001).

Table 5. ***Passage of starch and crude protein to the duodenum and their digestibility in the rumen of cows***

	Diets		Signif. of differnces
	Crushed wheat	Ground wheat	
Starch			
Intake, g/day	2761	2396	*.
Passage to the duodenum, g/day	268	257	
% of intake	9.7	10.2	n.s.
Crude protein (Nx6.25)			
Intake, g/day	1346	1242	*
Passage to the duodenum, g/24 h	1438	1263	
% of intake	106.8	101.8	n.s.

P <0.05; n.s. P>0.05

Several authors have reported a higher flow of crude protein to the duodenum of cows than the crude protein intake with maize, wheat, barley or tapioka grains as starch sources (Lebzien et al., 1983; Lebzien et al., 1996; Matthé 2001; Čerešňáková et al., 2004). Our experiment revealed the higher flow of crude protein and amino acids from the rumen than their intake, except flow of total amino acids with ground wheat (Table 5 and 6). These data document the utilisation of nitrogen released by degradation of wheat grain treated by both methods, and urea nitrogen from the rumeno-hepatic cycle in microbial protein synthesis. The extent of microbial proteosynthesis in the rumen depends on the amount of digested saccharides in the rumen.

Crude protein flow to the duodenum amounted to 106.8 % of the ingested crude protein with crushed wheat and 101.8 % with ground wheat. The difference was not significant.

With the exception of Leu, His, Met, Asp, Glu, and Pro, the passage of amino acids to the duodenum was higher than their intake for crushed wheat (Table 6). For ground wheat, more amino acids did not reach the level of their intake, the lowest was Pro (48 %). The highest increase in comparison with intake was observed in essential lysine and tyrosine and non-esential glycine.

The results of this experiment confirmed that wheat treated by crushing and/or grounding is most suitable starch source of energy for microbial protein synthesis when diets are well balanced. Crushed and/or ground wheat are not suitable products for increasing of starch flow to the duodenum.

Table 6. ***Amino acids passage to the duodenum (g / 24 h and % of intake)***

AA	Crushed wheat		Ground wheat		Sign diff.
	g/24h	% of intake	g/24h	% of intake	
THR	52.8±0.78	122.7±2.94	54.2±1.28	128.3±2.60	*
VAL	52.5±5.49	103.0±10.07	51.7±0.95	88.4±4.30	N.S.
ILEU	45.4±4.65	117.2±11.36	44.7±0.79	100.4±5.39	N.S.
LEU	77.9±7.97	98.5 ± 9.15	75.3±0.56	89.0±3.19	N.S.
TYR	64.8±10.06	143.0±21.11	59.6±2.87	129.3±5.68	N.S.
PHE	48.2±5.15	103.9±10.09	46.7±0.46	95.4±3.16	N.S.
HIS	28.3±2.52	77.7±6.04	27.2±0.64	83.8±2.63	N.S.
LYS	75.7±7.65	155.8±14.37	72.2±0.29	140.8±6.0	N.S.
ARG	54.5±5.71	107.3±10.10	52.7±0.26	99.8±5.68	N.S.
MET	15.8±2.41	91.0±12.07	15.5±0.52	93.4±1.23	N.S.
ΣEAA	516.0±51.87	113.0±10.35	499.9±4.80	104.5±3.48	N.S.
CYS	15.8±2.59	107.7±14.98	14.9±0.51	88.4±3.72	N.S.
ASP	117.1±11.67	88.0±8.09	112.0±2.05	86.1±1.64	N.S.
SER	54.1±2.82	115.1±5.11	53.5±1.43	108.3±2.12	N.S.
GLU	123.2±16.28	75.3±8.52	120.6±1.87	72.0±5.07	N.S.
PRO	47.9±3.75	54.5±3.83	45.2±0.77	48.4±1.46	*
GLY	94.9±8.92	180.0±14.24	95.5±2.83	186.4±3.22	N.S.
ALA	68.9±7.70	114.2±11.56	66.8±1.62	110.4±2.33	N.S.
ΣNEAA	522.0±53.10	93.3±8.26	508.5±8.09	89.3±2.91	N.S.
ΣAA	1038.0±104.2	102.2±9.12	1008.4±12.9	96.3±3.19	N.S.

p <0.05; N.S. P>0.05

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