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THE EFFECT OF WHEAT AND MAIZE MEAL ON RUMEN FERMENTATION AND APPARENT NUTRIENT DIGESTIBILITY IN CATTLE

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ABSTRACT

Starch is the major energy component of grains. The variability of wheat and maize starch degradation in the rumen influences the fermentation process and nutrient digestibility in ruminants. We studied effects of feeding diets with different starch sources on fermentation in the rumen and apparent nutrient digestibility. The experiment was performed on four Black-Spotted bulls (mean live weight of 525 kg) fitted with rumen fistula. The basis of the diets was maize silage and alfalfa hay supplemented with wheat meal (*W)*, or maize meal (*M)* in the diet. The ratio of starch to crude fibre (CF) was the 2.1:1 and the proportion of CF was maintained at 17% (DM) in both diets. Rumen fluid was collected prior to the morning feeding and 1, 2, 4 and 6 hours after feeding over three days. In the experimental period, two 96 h quantitative collections of faeces were done. Differences between treatments were evaluated by *t*-test using the Statgraphics, Version 5.0 software. Statistical significance of differences was declared at $P \leq 0.05$ and $P \leq 0.01$. Starch origin affected rumen fermentation significantly. Concentrations of propionic, butyric and lactic acid were higher with wheat than with maize meal. Large amounts of fermentable starch included in rations reduced rumen pH as a consequence of increased concentrations of propionic, butyric and lactic acid. Nutrient digestibility was influenced by different starch sources. The apparent digestibility of the dry matter (76 ± 2%), crude protein (67 ± 0.9%), CF (64 ± 1.9%), nitrogen-free extract (82 ± 1.5%) and organic matter (76 ± 1.3%) was significantly higher when experimental ration was supplemented with wheat meal.

Key words: wheat; maize; starch; rumen fermentation; digestibility of nutrients

INTRODUCTION

Carbohydrates are an important component of dairy cow diets. The variability of non-structural carbohydrate degradation in the rumen influences the fermentation process (Kováčik et al., 2003; Kopčeková, et al., 2008), passage of nutrients into small intestine (Čerešňáková et al., 2006) and nutrient digestibility in ruminants (Pajtáš and Šimko, 2003). The energy efficiency of starch fermented in the rumen to volatile fatty acids is lower than that of starch absorbed in the small intestine (Weurding and Poel, 1998). Therefore, the increase in starch content and its flow into the small intestine is important for energy supply in high-yielding dairy cows consuming large amounts of dietary starch from various feedstuffs. Depending on the starch source and amount, approximately 50-95% of dietary starch is fermented to volatile fatty acids (Sniffen et al., 1992). Starch fermentation in the rumen results in approximately a 40% decline in caloric efficiency compared to enzymatic starch digestion in the small intestine (Owens et al., 1986). The rate and extent of starch digestion in the rumen are affected by the structure of starch in individual types of grain (French, 1973; Kotarski et al., 1992). In addition, there are large differences among cereals in starch degradability within the rumen. According to many

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authors, wheat starch degradability in the rumen is higher than that of maize starch (Lebzien and Engling, 1995; Zebrowska et al., 1997; Kopčeková and Čerešňáková, 2003; Čerešňáková et al., 2006).

The objective of the present work was to determine the influence of two starch sources (wheat and maize) on rumen fermentation and the apparent digestibility of nutrients.

MATERIALS AND METHODS

Four bulls of the Black-Spotted cattle breed with average live weight of 525 ± 32 kg were used in the experiment. Animals were fitted with a large rumen cannula (Bar Diamont, Inc., USA). The bulls were fed individually two times daily at 06.30 and 18.30 h. Water was available *ad libitum*. Two diets supplemented with wheat or maize meal were examined in the experiment (Table 1). The experimental rations contained maize silage, alfalfa hay and the same amounts (3.4 kg DM) of maize (M) or wheat (W) meal. Contents of dry matter, energy and nutrients in the diets are shown in Table 1. The ratio of starch to CF was held constant in both diets (Table 2). Each experimental period lasted three weeks. After eleven days of adaptation, two 96 h quantitative collections of faeces were done. From every 24 h-collected samples after homogenization the subsample (3% of total amount of faeces per animal) was taken for chemical analyses. Ruminal fluid was collected prior to the morning feeding and 1, 2, 4 and 6 hours after feeding on days 5, 6 and 7.

Chemical composition of feeds was determined by Weende analysis (the Regulation of the Slovak Ministry of Agriculture no. 2145/2004-100). Starch content was determined by the enzymatic method according to Salomonsson et al. (1984). Rumen pH was measured immediately after each sampling, VFA concentration was determined using gas chromatography on a 1.8 m column with 10% SP1200 and 1 % H_3PO_4 on Chromosorbe WAW 80/100 mesh with isocaprylic acid as an internal standard (GC Carlo Erba). Ammonia concentration was measured by the Conway method (Voight and Steger, 1967). Differences between treatments were evaluated by *t*-test using Statgraphics, Version 5.0. Statistical significance of differences was declared at $P \leq 0.05$ and $P \leq 0.01$.

RESULTS AND DISCUSSION

In our experiment the proportion of wheat meal and maize meal in the dry matter of the feed rations was 34% (Table 1). Intake of dry matter, energy and nutrients from the rations is shown in Table 2. The ratio of starch to fibre was held constant at 2.1:1 and the percentage of CF was maintained at 17 % (DM).

Large amounts of fermentable starch included in rations reduce ruminal pH as a consequence of increased

Table 1: Feed and nutrient composition of the experimental diets

Ingredient	Diets			
	W		M	
	kg DM	%	kg DM	%
Maize silage	5.0	50	4.7	47
Alfalfa hay	1.6	16	1.9	19
Wheat meal	3.4	34	-	-
Maize meal	-	-	3.4	34
Total	10.0	100	10.0	100

Chemical composition of experimental feeds

Feed	n = 6	Maize silage	Alfalfa hay	Wheat meal	Maize meal
DM	g.kg^{-1} FM	356	888	881	892
NEL	MJ.kg^{-1} DM	6.29	4.65	8.80	9.00
NEV	MJ.kg^{-1} DM	6.28	4.26	9.54	9.78
PDI	g.kg^{-1} DM	52	107	94	66
CP	g.kg^{-1} DM	86	178	149	90
Fat	g.kg^{-1} DM	31	22	17	41
NFE	g.kg^{-1} DM	624	382	776	825
Starch	g.kg^{-1} DM	273	36	612	701
CF	g.kg^{-1} DM	213	319	33	29
OM	g.kg^{-1} DM	954	901	976	985
Ash	g.kg^{-1} DM	46	99	24	15

DM – dry matter; FM – fresh matter; NEL – net energy of lactation; NEV – net energy of gain; CP – crude protein; NFE – nitrogen-free extract; CF – crude fibre; OM – organic matter; **PDI – protein digestible** in intestine

Table 2: Daily intake (g) of dry matter, energy and nutrients from the experimental diets

Intake			Diet	
			W	M
DM		g	8958	9261
Energy	NEL	MJ	61.9	63.0
	NEV	MJ	63.2	64.7
Nutrients	PDI	g	664	627
	Crude protein	g	1079	977
	Fat	g	225	292
	Nitrogen-free extract	g	5711	5844
	Starch	g	3115	3386
	Crude fibre	g	1501	1592
	Organic matter	g	8516	8704
ratio of starch to fibre			2.1 : 1	2.1 : 1
percentage of fibre			16.8	17.2

DM – dry matter; NEL – net energy of lactation; NEV – net energy of gain; PDI – protein digestible in intestine

concentrations of propionic, butyric and lactic acid (De Visser et al., 1980; Kováčik et al., 2002; Plaizier et al., 2008). Propionic acid, which is produced by starch fermenting bacteria (¨rskov, 1986; Čereďňáková et al., 2006), reached a maximal concentration within one hour after feeding. The diet with wheat meal caused an increase in the concentration of butyric acid. The concentration of butyric acid was significantly higher with wheat meal than with maize meal. In sacco results with maize grain show a slower degradation of the crude protein compared to other cereals (Tamminga et al., 1990; Zebrowska et al., 1997; Čerešňáková et al., 2000). In contrast, the increased loss of N from the wheat meal resulted in increase in N-NH_3 concentration in the rumen fluid throughout the observation period.

The impact of maize and wheat meal on total tract apparent digestibility of nutrients is shown in Figure 1.

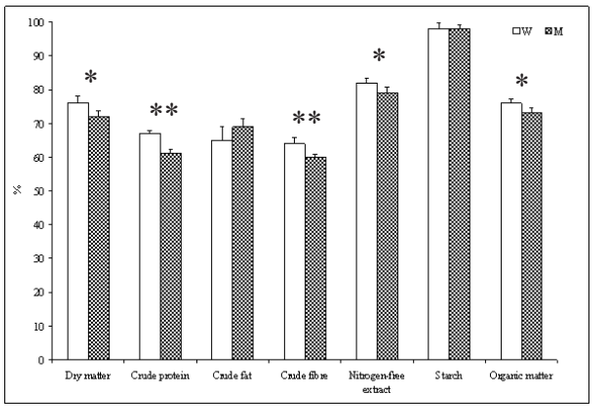

Fig. 1: Total tract apparent digestibility of nutrients (%), *P ≤ 0.05; **P ≤ 0.01

Nutrient digestibility was influenced by different starch sources. The apparent digestibility of the dry matter (76%), crude protein (67%), fibre (64%), nitrogen-free extract (82%) and organic matter (76%) was significantly higher when feeding a wheat meal was performed. The apparent digestibility of starch was not significantly influenced by different starch sources. In both cases, starch digestibility was 98% despite different starch intakes (in diet *W* starch intake was 3115 g per day, in diet *M* 3386 g per day). From previous research, we know that apparent digestibility of starch is not significantly affected by the diet at low intakes. Reynolds et al. (1997) did not detect any influence on starch digestibility with rations providing a starch intake of 4-11 kg per day. Also, Beckman and Weiss (2005) did not detect significant differences in starch digestibility when the intake of starch in rations varied. De Visser (1980), Klejmenov et al. (1986) and Robinson et al. (1987) reported that by increasing the ratio of starch in feeding rations the digestibility of organic matter and crude protein increases. However, the source of starch in the diet may influence this response.

SUMMARY

Different starch sources (wheat and maize) significantly changed ruminal pH, as a consequence of increased concentrations of propionic, butyric and lactic acid. The concentrations of propionic, butyric and lactic acid were significantly higher with wheat meal than with maize meal. The apparent digestibility of dry matter, crude protein, fibre, nitrogen-free extract and organic matter was significantly higher when wheat meal was given. The apparent digestibility of starch was not significantly influenced by different starch sources.

Table 3: Changes of pH in the rumen fluid

Hours after a.m. feeding	Diet						P (t – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	6.64	0.22	3.38	6.86	0.17	2.52	-
1	5.89	0.28	4.68	6.16	0.19	3.02	++
2	5.78	0.23	3.94	6.03	0.22	3.57	+
4	5.43	0.31	5.78	6.08	0.19	3.18	++
6	5.84	0.26	4.46	6.35	0.21	3.34	++

$\bar{x}$ - average; s - standard deviation; v - coefficient of variation $^{+}P \leq 0.05$ $^{++}P \leq 0.01$

Table 4: Changes in acetic acid concentration in the rumen fluid (mmol/l)

Hours after a.m. feeding	Diet						P (*t* – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	57.02	6.45	11.31	58.55	10.12	17.29	-
1	66.06	7.42	11.24	70.10	12.84	18.32	-
2	67.97	4.37	6.44	69.64	14.62	20.99	-
4	73.71	5.71	7.75	77.03	4.78	6.21	-
6	69.63	5.58	8.01	72.35	6.77	9.36	-

$^{+}P \leq 0.05$ $^{++}P \leq 0.01$

Table 5: Changes in propionic acid concentration in the rumen fluid (mmol/l)

Hours after a.m. feeding	Diet						P (*t* – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	11.86	1.56	13.17	9.93	1.10	11.16	++
1	19.44	2.29	11.80	16.70	1.28	7.66	++
2	19.36	1.37	7.08	15.41	1.01	6.58	++
4	18.19	1.39	7.62	14.07	1.12	7.94	++
6	15.43	1.78	11.56	12.01	1.15	9.61	++

$^{+}P \leq 0.05$ $^{++}P \leq 0.01$

Table 6: Changes in butyric acid concentration in the rumen fluid (mmol/l)

Hours after a.m. feeding	Diet						P (*t* – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	11.08	1.33	11.99	8.49	1.25	14.69	++
1	13.32	1.92	14.39	11.10	1.69	15.24	++
2	13.93	1.02	7.32	11.84	1.21	10.17	++
4	15.51	1.26	8.13	12.31	1.46	11.89	++
6	14.32	1.95	13.59	11.68	1.51	12.96	++

$^{+}P \leq 0.05$ $^{++}P \leq 0.01$

Table 7: Changes in lactic acid concentration in the rumen fluid (mmol/l)

Hours after a.m. feeding	Diet						P (*t* – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	0.65	0.20	31.41	0.48	0.17	35.67	+
1	0.99	0.45	45.75	0.58	0.23	40.35	+
2	0.76	0.19	25.01	0.54	0.12	23.18	++
4	0.68	0.15	21.42	0.43	0.17	40.32	++
6	0.68	0.15	21.42	0.45	0.15	34.70	++

$^{+}P \leq 0.05$ $^{++}P \leq 0.01$

Table 8: Changes in ammonia-N concentration in the rumen fluid (mg/100 ml)

Hours after a.m. feeding	Diet						P (*t* – test)
	W			M			
	$\bar{x}$	s	v	$\bar{x}$	s	v	
0	8.4	1.1	13.31	6.0	1.9	31.15	-
1	22.9	2.8	12.25	21.1	2.3	10.81	-
2	20.6	2.2	10.81	18.0	1.7	9.48	++
4	10.1	2.5	24.97	5.5	1.8	31.85	++
6	5.0	2.0	39.48	3.2	1.7	53.91	-

$^{+}P \leq 0.05$ $^{++}P \leq 0.01$

REFERENCES

BECKMAN, J. L. – WEISS, W.P. 2005. Nutrient digestibility of diets with different fiber to starch ratios when fed to lactating dairy cows. *Journal of Dairy Science*, 88, 2005, p. 1015-1023.

ČEREŠŇÁKOVÁ, Z. – SOMMER, A. – CHRENKOVÁ, M. – POLÁČIKOVÁ, M. – DOLEŠOVÁ, P. – KRÁĽOVÁ, V. 2000. Effective protein degradability and changes in amino acid spectrum after incubation of grains and mill feeds in rumen. *Czech Journal of Animal Science*, 45, 2000, p. 355-360.

ČEREŠŇÁKOVÁ, Z. – CHRENKOVÁ, M. – SOMMER, A. – FĽAK, P. – POLÁČIKOVÁ, M. 2006. Origin of starch and its effect on fermentation in the rumen and amino acids passage to the intestinum of cows. *Slovak Journal of Animal Science*, 39, 2006, p. 10-15.

FRENCH, D. 1973. Chemical and physical properties of starch. *Journal of Animal Science*, 37, 1973, p. 1048-1061.

KLEJMENOV, N. I. – GRUZDEV, N. V. – KURILOV, P. N. – POLEŽAJEV, V. V. – MICHAJLOV, V. V. 1986. Raciony s različnym urovnem legkoperevarimych uglevodov i proteina. *Životnovodstvo*, 1, 1986, p. 36-38.

KOPČEKOVÁ, J. – ČEREŠŇÁKOVÁ, Z. 2003. Effect of mechanical processing wheat and maize corn on ruminal degradability of selected nutrients. *Agriculture*, 49, 2003, p. 514-518.

KOPČEKOVÁ, J. – ČEREŠŇÁKOVÁ, Z. – ŠIMKO, M. – FĽAK, P. – MLYNEKOVÁ, Z. 2008. Effect of physical processing of cereals on rumen crude protein degradability. *Slovak Journal of Animal Science*, vol. 41, 2008, no. 4, p. 160-165.

KOTARSKI, S. F. – WANISKA, R. D. – THURN, K.K. 1992. Starch hydrolysis by the ruminal microflora. *Journal of Nutrition*, 122, 1992, p. 178-190.

KOVÁČIK, J. – BÍRO, D – FABIŠ, M. – BUDÁČOVÁ, A. – MASSANYI, P. 2002. Zmeny niektorých ukazovateľov vnútorného prostredia dojníc počas kritických biologických fáz. [The changes of selected parameters of dairy cows internal milieu during critical biological phases]. *Agriculture*, roč. 48, 2002, č. 5, s. 232-236.

KOVÁČIK, J. – FABIŠ, M. – KOLESÁROVÁ, A. – MASSANYI, P. – KRAMÁROVÁ, M. 2003. Vplyv metabolickej záťaže dojníc na niektoré ukazovatele vnútorného prostredia. [The effect of metabolic stress of dairy cows on selected parameters of internal milieu] In: *5. Slovak seminar of Animal Physiology*. Nitra : SPU, 2003, s. 94-97.

LEBZIEN, P. – ENGLING, F. P. 1995. On the influence of two rations of grass-silage and concentrates mixtures with different sources of carbohydrates on rumen fermentation and nutrient digestibility in dairy cows. *Journal of Animal Physiology and Animal Nutrition*, 74, 1995, p. 208-218.

ØRSKOV, E.R. – FRASER, C. – MCDONALD, L. 1986. Digestion of concentrates in sheep 3. Effects of rumen fermentation of barley and maize diets on protein digestion. In: *British Journal of Nutrition*, 26, 1986, p. 477-486.

OWENS, F. N. – ZINN R, A. – KIM Y, Z. 1986. Limits to starch digestion in the ruminant small-intestine. *Journal of Animal Science*, 63, 1986, p. 1634-1648.

PAJTÁŠ, M. – ŠIMKO, M. 2003. Influence of maize groats and wheat groats on digestibility of nutrients and nitrogen balance of young bulls. *Agriculture*, 49, 2003, p. 509-513.

PLAIZIER, J. C. – KRAUSE, D. O. – GOZHO, G. N. – MCBRIDE, B. W. 2008. Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences. *The Veterinary Journal*, 176, 2008, p. 21-23.

REYNOLDS, C. K. – SUTTON, J. D. – BEEVER, D. E. 1997. Effects of feeding starch to dairy cattle on nutrient availability and production. *Recent Advances in Animal Nutrition*, 1997, p. 105-134.

Regulation of the Slovak Ministry of Agriculture no. 2145/2004-100

ROBINSON, P. – TAMMINGA, S. – VANVUUREN, S.M. 1987. Influence of delining level of feed intake and varying the proportion of starch in the concentrate on milk production and whole tract digestibility in dairy cows. *Livestock Production Science*, 17, 1987, p. 19-35.

SALOMONSSON, A. C. – THEANDER, O. – WESTERLUND, O. 1984. Chemical characterisation of some Swedish cereal whole meal and brain fractiond. *Swedish Journal of Agricultural Research*, 14, 1984, p. 111-117.

SNIFFEN, C. J. – O'CONNOR, J. D. – VAN SOEST, P. J. – FOX, D. G. – RUSSELL, J. B. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availabilite. *A. Anim. Sci*, 70, 1992, s. 3562-3577.

DeVISSER, H. 1980. Het effect van het percentage zatmmeel en suikers in rundveevoeders op de voaderpname en de gelovgen daarvan voor de melkproduktie. In: *Badrijfsontwikkeling*, 11, 1980, p. 1041-1047.

TAMMINGA, S. – VAN VUUREN, A. M. – VAN DER KOOLEN, C. J. – KETELAAR, R. S. – VAN DER TOGHT, P. L. 1990. Ruminal behaviour of structural carbohydrates, non structural carbohydrates and crude protein from concentrate ingredients in dairy cows. *Netherlands Journal of Agricultural Science*, 38, 1990, p. 513-526.

VOIGHT, J. – STEGER, H. 1967. Zur quantitativen Bestimmung von Ammoniak, Harnstoff und Ketokörpen in biologichem Material mit Hilfe eines modifizierten Mikrodiffusionsgefässes. *Archiv Tierernährung*, 17, 1967, p. 289-293.

WEURDING, E. – POEL, T. 1998. Processing alters starch degradation in dairy feeds. *Feed Technol*, 2, 1998, p. 31-33.

ZEBROWSKA, T. – DLUGOLECKA, Z. – PAJAK, J.J. – KORCZYNSKI, W. 1997. Rumen degradability of concentrate protein, amino acids and starch, and their digestibility in the small intestine of cows. *Journal of Animal and Feed Technology*, 6, 1997, p. 451-470.