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EFFECT OF PHYSICAL PROCESSING OF CEREALS ON RUMEN CRUDE PROTEIN DEGRADABILITY

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ABSTRACT

The extent of crude protein (CP) degradation in the rumen is an important parameter for prediction of protein supplying for the rumen microorganisms as well as the supply of the ruminant animal with amino acids. Therefore the protein degradability of the feedstuffs becomes an essential characteristics in determining the protein value of the feeds. The protein degradation in the rumen varies considerably between feeds and within feeds. Different chemical or physical treatments of the feed can influence the degradability also. The objectives of this study was to determine the effect of particle size (≤ 1.4, 1.5-2.5, 2.6-3.0 and > 3,0 mm) of processed wheat, barley and maize on ruminal degradability and the parameters of effective crude protein degradability by in sacco method. Among cereals, wheat had the highest effective crude protein degradability (76.4-85.9 %), the lowest was found in maize (28.0-58.6 %). Reduction in particle size increased degradability of crude protein in all grains. Effective degradability was the highest for the smallest particles (≤ 1.4 mm), 85.9 % for wheat, 79.8 % for barley and 58.6 % for maize. These results indicate that optimal degree is coarsely grinding, because larger particles caused the lower ruminal degradability and increased passage of undegraded CP to the duodenum.

Key words: cereals, grain processing, particle size, in sacco crude protein degradability

INTRODUCTION

Cereals are described as saccharide feeds in nutrition of ruminants; they provide the organism of animals with necessary energy, and their share in supplying the animals with nitrogen is also not negligible. At present, assessment of ruminant feed quality takes into consideration not only the content of nutrients in feed but also the level of their degradation in rumen. This is important mainly for high-yielding animals, from the viewpoint of crude protein quality evaluation in concentrates, the level of degradability of crude protein and the amount of amino acids, which come into small intestine from the original feed (Madsen and Hvelplund, 1985).

Whole grain with intact pericarp is very resistant to bacterial digestion in rumen. Feed particles after crushing have larger surface area that is better accessible to rumen microorganisms and their enzymes, which is a prerequisite for quicker degradation in rumen. Moe and Tyrrell (1977) reported that reduction in the size of particles increases the surface area accessible to microorganisms exponentially. It is possible to influence degradability not only by changing the crude protein source but also by suitable mechanical, physical or chemical treatment of cereals, or by stage of their ripeness (Hric et al., 2000). As grinding is the most widespread technology of cereal treatment, this work concerned with the effect of different particle size of grounded wheat, barley and maize grain on rumen degradability of crude protein.

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MATERIALS AND METHOD

Standardized *in sacco* method (Harazim and Pavelek, 1999) was used to assess the degradability of crude protein (CP) in physically treated grain crops with incubations for 0, 3, 6, 9, 16, 24 hours, and also 48 hours for maize. Effective degradability (EDg) was calculated out of crude protein degradabilities in individual incubations by means of Neway programme (Rowett Research Institute) as mentioned by Orskov and McDonald (1979), at passage speed of 0.06 and $0.08.h^{-1}$. In the tested feeds and in remnants after incubations the contents of dry matter and crude protein were determined according to Decree of MA SK 1497/4/1997-100.

Maize (DK 471), winter wheat (Brea) and spring barley (Jubilant) were used as experimental material. Feed samples were treated by grinding in grain hammer mill. Crushed feeds were sieved through different size of openings for obtaining particles of different sizes (tab. 1).

Tab. 1: Particle size of individual feeds

used screen size of sieves (mm)	particle size (mm)	share of fraction after grinding of 1 kg meal (%)		
		[4]wheat	[5]barley	[6]maize
1,4	≤ 1,4	33,93 (P1)	29,77 (J1)	19,64 (K1)
2,5	1,5-2,5	30,62 (P2)	35,68 (J2)	59,17 (K2)
3,0	2,6-3,0	19,46 (P3)	20,25 (J3)	11,81 (K3)
	> 3,0	15,99 (P4)	14,30 (J4)	9,38 (K4)

Experiments were performed with two dry cows of Black Spotted breed; average live weight 645 kg, equipped with large rumen cannula (Ø 10.5 cm). Ration consisted of lucerne hay (4 kg), maize silage (6 kg), concentrates (2 kg, wheat and barley in ratio 1:1), mineral-vitamin additive. Roughages represented 75% out of total dry matter content in ration. Feed ration covered maintenance requirement, and level of nutrition did not exceed 1.5 times of maintenance requirement. Animals were fed two times a day, at 6.00 and 18.00 hr. Water was at disposal *ad libitum*.

Observations of studied parameters of CP degradability were evaluated mathematically and statistically - basic variation-statistical characteristics for individual studied factors (feed, treatment, incubation period) were determined. Evaluation started from studied factors and obtained data was evaluated by means of two or three way variance analyses of the mentioned factors and their interactions. With regard to the significance of interactions of feed and treatment or feed and incubation period, the concerned interactions were depicted graphically, estimating also the linear and quadratic functions of parameters from treatment (size of particles) or since incubation period. Used mathematical and statistical models were applied in statistical package Statistix 8.0 after Grofik and Flak (1990), and Microsoft Office Excel 2007 computer program was used for graphical processing.

RESULTS AND DISCUSSION

Amount of CP feed, which gets into small intestine of ruminants, depends on total amount of CP in feed and its degradability in rumen. CP content in maize grain is quite low. Loose et al. (1998) reported 74 – 96 g CP content per one kilogram dry matter from twenty varieties of maize, which corresponds also with our results. In individual maize fractions average CP content was $84.10\ g.kg^{-1}$ of dry matter, which is considerably less compared with wheat, where the average content was $118.80\ g.kg^{-1}$ of dry matter. The lowest average CP content was reported from barley ($85.60\ g.kg^{-1}$ of dry matter).

Linear and quadratic dependence of CP disappearance in individual feeds with different size of particles and with regard to incubation period was also studied. Quadratic dependences were also represented graphically for better documentation of evidence (Fig. 1 – 3). The highest disappearance of CP in wheat was during the first three hours of incubation (except for variant P4), while 37.10 – 70.40 % CP was degraded in rumen. A marked increase was noticed in disappearance in variant P4 after 6 hours of incubation. With prolongation of incubation period to 24 hours degradation continued until it reached values for individual variants from 94.10% (variant P4) to 97.60% (variant P2). The course of degradation in wheat grain with the smallest size of particles (P1) differed from other variants as higher disappearance was noticed already at hour 0 (63.30%). Herrera-Saldana et al. (1990) observed CP disappearance from grounded grain crops sieved through 1 mm sieve; after 12 hours incubation in rumen they assessed more than 98% disappearance in wheat and barley while less than 80% maize was degraded in rumen.

Linear and quadratic dependences of CP disappearance in wheat were statistically significant to highly significant (Tab. 2). Quadratic course of CP disappearance (effect of treatment; Fig.1) had high coefficients of determination from $R^2 = 0.9462^{+}$ (P2) to $R^2 = 0.9766^{++}$ (P3). Increase in CP disappearance was basically the same for P2 – P4, and somewhat lower for P1.

Tab. 2: Summary of linear (L) and quadratic (Q) functions of crude protein disappearance in wheat influenced by incubation time and particle size

Fraction n=6	Function	a	b	c	R^2	R^2_α
P1	L	71,5000	1,3633		0,7094	+
	Q	62,8760	4,1522	-0,1149	0,9482	+
P2	L	48,2380	2,5460		0,6948	+
	Q	31,5370	7,9469	-0,2225	0,9462	+
P3	L	39,0270	2,8499		0,8256	+
	Q	25,7370	7,1481	-0,1771	0,9766	++
P4	L	34,5830	2,8698		0,8587	++
	Q	23,4050	6,4848	-0,1489	0,9682	++

$R_{0,05}$ (1, 4) = 0,8110 $R^2_{0,05}$ (1, 4) = 0,6577; $R_{0,01}$ (1, 4) = 0,9170 $R^2_{0,01}$ (1, 4) = 0,8408
$R_{0,05}$ (2, 3) = 0,9300 $R^2_{0,05}$ (2, 3) = 0,8649; $R_{0,01}$ (2, 3) = 0,9770 $R^2_{0,01}$ (2, 3) = 0,9545

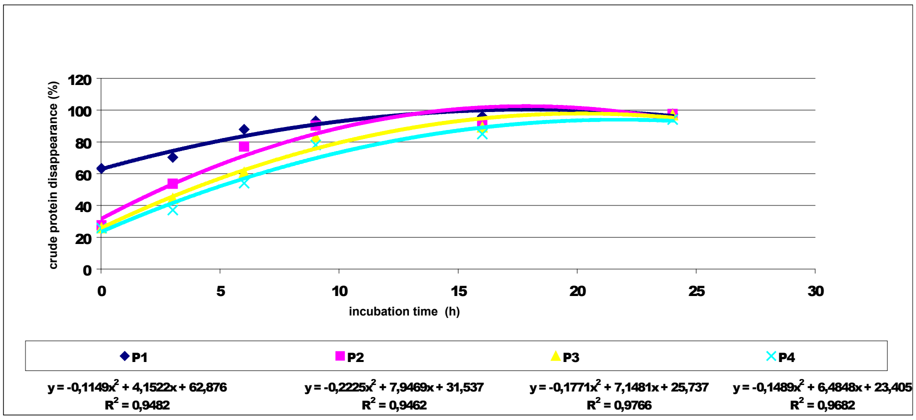

Fig. 1: Quadratic relationship of crude protein disappearance between incubation time and feed particle size in wheat

Similarly, higher losses were noticed by washing in the fraction of barley with the smallest size of particles (J1) compared with others. CP disappearance in rumen from J1 to J4 was more than 90% after 16 hours of incubation. It achieved 95.66% in variant J2 after 24 hours of incubation, and it was the lowest in J4 (91.86%).

Quadratic dependences of CP disappearance in barley were statistically significant to highly significant. Regression coefficient was the lowest for J1 (b=3.9830 %) and rose up to b=6.3634 % for J4 (Tab. 3). Quadratic course of CP disappearance with determination coefficients from R^2=0.8925$^+$ with J1 to R^2=0.9945^{++} with J3 is presented in Fig. 2.

Tab. 3: Summary of linear (L) and quadratic (Q) functions of crude protein disappearance in barley influenced by incubation time and particle size

Fraction n=6	Function	a	b	c	R^2	R^2_α
J1	L	64,7150	1,4733		0,7624	+
	Q	56,9550	3,9830	-0,1034	0,9403	+
J2	L	41,9290	2,6782		0,7096	+
	Q	27,1010	7,4735	-0,1976	0,8925	+
J3	L	35,7940	2,9487		0,8342	+
	Q	21,7010	7,5063	-0,1878	0,9945	++
J4	L	29,4600	3,0140		0,8908	++
	Q	19,1030	6,3634	-0,1380	0,9793	++

$R_{0,05}$ (1, 4) = 0,8110 $R^2_{0,05}$ (1, 4) = 0,6577; $R_{0,01}$ (1, 4) = 0,9170 $R^2_{0,01}$ (1, 4) = 0,8408
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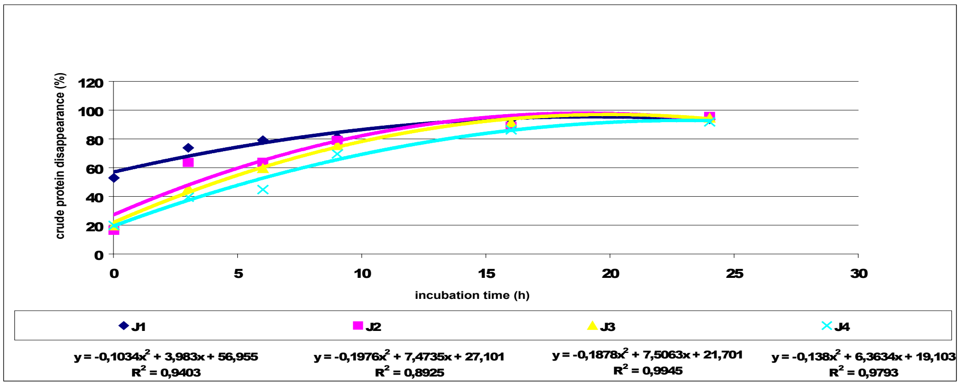

Fig. 2: Quadratic relationship of crude protein disappearance between incubation time and feed particle size in barley

CP disappearance from maize particles of different sizes during incubation period in rumen was considerably lower than in wheat and barley. Almost six times higher losses were noticed with K1 by washing (0 hr) than with K2, K3 or K4. CP degradability varied from 53.86% (K4) to 75.86% (K1) after 24 hours of incubation. CP degradation exceeded the limit of 90% after 48 hours of incubation with the exception of K4 fraction, where the value was 87.20%.

In maize the linear and quadratic dependences of CP disappearance was highly significant for all four fractions. Quadratic course of CP disappearance (Fig. 3) had the coefficients of determination from R^2=0.9644^{++} (with K1) to R^2=0.9928^{++} (with K3). With the size of maize particles (from K1 to K4), increase in CP disappearance was characterized by increasing regression coefficients (Tab. 4).

Tab. 4: Summary of linear (L) and quadratic (Q) functions of crude protein disappearance in maize influenced by incubation time and particle size

Fraction n=6	Funkcia	a	b	c	R^2	R^2_{α}
K1	L	43,3850	1,3300		0,9643	++
	Q	43,5250	1,2848	0,0019	0,9644	++
K2	L	26,3400	1,7008		0,9641	++
	Q	24,9280	2,1574	-0,0188	0,9697	++
K3	L	17,0090	1,7579		0,9806	++
	Q	14,8760	2,4476	-0,0284	0,9928	++
K4	L	9,5976	2,0010		0,9687	++
	Q	6,6659	2,9490	-0,0391	0,9862	++

$R_{0,05}$ (1, 4) = 0,8110 $R^2_{0,05}$ (1, 4) = 0,6577; $R_{0,01}$ (1, 4) = 0,9170 $R^2_{0,01}$ (1, 4) = 0,8408
$R_{0,05}$ (2, 3) = 0,9300 $R^2_{0,05}$ (2, 3) = 0,8649; $R_{0,01}$ (2, 3) = 0,9770 $R^2_{0,01}$ (2, 3) = 0,9545

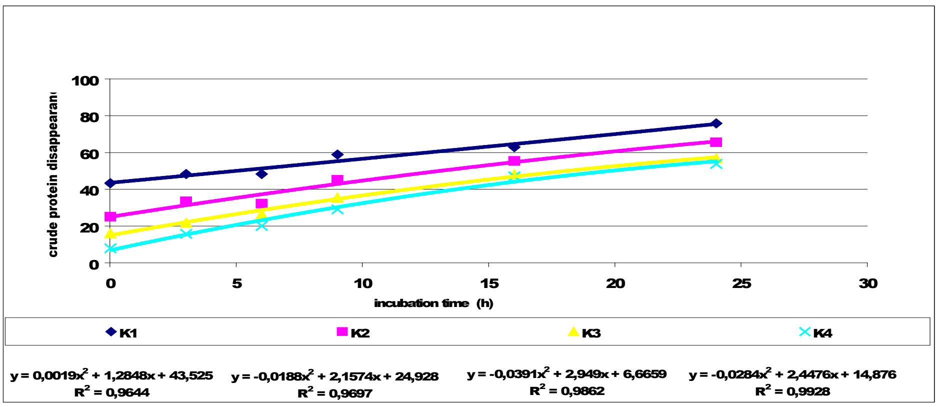

Fig. 3: Quadratic relationship of crude protein disappearance between incubation time and feed particle size in maize

Tab. 5: Characteristics of crude protein degradability of processing feeds after incubation in rumen

Fraction	[1]a	[2]b	[3]c	[4]EDg (%)	
	%	%	%.h-1	0,06.h-1	0,08.h-1
P1	22,5	74,4	0,345	85,9	82,9
P2	27,4	68,2	0,292	84,0	80,9
P3	25,7	71,9	0,170	78,8	74,6
P4	25,8	69,4	0,161	76,4	72,2
J1	52,9	46,8	0,081	79,8	76,4
J2	16,4	83,6	0,060	58,2	52,2
J3	19,6	79,8	0,131	74,3	69,1
J4	19,9	80,1	0,097	69,4	63,8
K1	43,4	56,6	0,022	58,6	55,6
K2	25,1	74,9	0,015	40,1	36,9
K3	16,0	84,0	0,010	28,0	25,3
K4	7,9	92,1	0,021	31,8	27,0

[1]Rapidly soluble fraction; [2]Potentially degradable fraction; [3]Rate constant of degradation; [4]Effective degradability

Characteristics of degradability and effective degradability of CP

Effective CP degradability (EDg) in grain crops ranges from 74 to 92% (Żebrowska et al., 1997). Lebzien and Engling (1995) also reported similar values: 89% rumen degradability for wheat, 81% for barley and 69% only for maize. Among individual species and varieties of grain feeds there are differences in their degradation, resulting from chemical composition and physical structure, which becomes evident in the span and speed of their change in rumen (Matthé, 2001). Significant differences in effective degradability of crude protein among various varieties of wheat were reported by Čerešňáková et al. (2003).

At present, there are few available works, which characterize rumen degradability of CP from grain crops treated in different ways. In this study, a very quick degradation of fraction "b" (0.161 – 0.345 %.h^{-1}) for wheat and a quite high proportion of soluble fraction "a" was seen. Effective CP degradability in wheat decreased with enlarging size of particles and it varied from 76.40% (P4) to 85.90% (P1) in individual fractions. Level of effective degradability is also influenced by speed of outflow of chyme from rumen (k_d). Vérité et al. (1990) reported the k_d value of 0.06 to 0.08 h^{-1} (Tab. 5) for concentrates. EDg decreases with increasing speed of passage.

Kopčeková et al. (2002) studied CP EDg in mashed and crushed wheat and maize and found higher CP EDg (70.20%) in grounded wheat than in crushed one (63.15%). For maize they assessed by 15 – 20% lower CP EDg. In this experiment, a very high percentage for quickly soluble and degradable fraction "a" (52.90%) in barley for fraction J1 was found in comparison with others. Degradation speed of fraction "b" varied from 0.060 – 0.131%.h^{-1}, and it was the highest in J3. CP EDg was the highest in J1 (Tab. 5) for barley too. Olaisen et al. (2003) observed CP EDg in barley and maize ground through a 1.5 mm sieve and they assessed the values 74.20% and 32.50%, respectively.

For individual maize fractions (K1 to K4) high values of degradable, water insoluble fraction "b" and its slow degradation (from 56.60% for K1 to 92.10% for K4) was noticed. For maize degradation speed of fraction "b" was the lowest with values for individual sizes of particles ranging from 0.010%.h^{-1} (K3) to 0.022%.h^{-1} (K1). Proportion of the quickly soluble fraction was the highest in K1 (43.40%). Lykos and Varga (1995) reported similar EDg values in maize they studied CP EDg in fine ground maize (average size of particles 686μm), 75.40% of particles being smaller than 500 μm and CP EDg were 53.30%.

Herrera – Saldana et al. (1990) observed CP EDg in 5 grain crops ground on 1 mm sieve. Effective CD degradability was 69.70% in maize, 94.70% in wheat and 91% in barley. Our EDg results are comparable with data published for maize, but higher for wheat and barley. Parameters of degradability are influenced by factors such as: grinding, size of sample, origin of grains, size of pores in sack, and ration for animals (Galyean et al., 1981). Grains were ground on 1 mm sieve and according to authors the high degradability can be explained by this small size of particles. According to Wohlt (1973), the amount of degraded CP is given by their solubility, which is determined by proportion of albumins, globulins, prolamins, glutelins and scleroproteins. Maize zein represents main storage proteins in maize, which are water-insoluble (Harper, 1979) because of their physical and chemical structure. Maize zein creates spatial structure by means of disulfide bridges, which restrains entry of proteolytic enzymes, and reduces not only the degradability of CP but also of starch (Kotarski et al., 1992).

CONCLUSION

Differences in span and speed of crude protein degradation between maize and wheat corn were confirmed in the experiment; they differ in all characteristics of degradation.

On the basis of these findings and from up to now published works it may be assumed that coarse grinding is more suitable treatment of feed because of lower effective degradability in rumen, which is a prerequisite for better utilization of nitrogen from grain crops in small intestine.

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