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AN ASSESSMENT OF DIFFERENCES IN THE RUMINAL DEGRADABILITY AND INTESTINAL DIGESTIBILITY OF CRUDE PROTEIN IN BREWER'S GRAINS AND MAIZE DRAFF

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Abstract

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The submitted thesis aims to assess the differences between the ruminal degradability and intestinal digestibility of crude protein contained in brewer's grains (BG) and maize draff (AMG). The effectiveness of ruminal degradability was tested using the "in sacco" method on 3 dry Holstain cows fitted with rumen cannulas. The dynamics of ruminal degradability of crude protein (CP) was detected after 0, 4, 8, 16, and 24 hours of samples incubation in the rumen. The intestinal digestibility of crude protein undegradable in the rumen was determined using the "mobile bag" method on 3 dry Holstain cows fitted with duodenal cannulas. The crude protein degradability of BG was detected in the above-mentioned hours (%): 4.06; 18.16; 32.40; 38.56, and 50.70; crude protein degradability of AMG: 42.04; 63.56; 84.47; 85.16, and 87.19. The effectiveness of rumen degradability of BG crude protein at the rate of passage of rumen content 6% per hour was calculated at 35.33% and that of AMG, at 76.29%. Intestinal digestibility of BG crude protein and dry matter at the rate of passage of intestinal content 6% per hour was calculated at 79.41% and 22.84%, respectively, and that of AMG, at 57.01% and 11.33%, respectively. The differences between the indicators of both feedstuffs were significant ($P < 0.05$). The results show that BG are mostly a source of crude protein with higher intestinal digestibility than AMG.

fresh brewer's grains, fresh maize draff, "in sacco" method, ruminal degradability, "mobile bag" method, intestinal digestibility

The increasing worldwide demand for raw materials for food production and the increasing pressure of food producers on improving the quality of raw cow milk and decreasing its price, require from breeders, not only in European Union countries, to pay greater attention to breeding from the view of both keeping the principles of free stabling and reaching the appropriate nutrition of animals. The aim of achieving the maximum sign of genetic potential through optimizing nutrition often makes dairy cow breeders increase the concentration of nutrients in feed rations. The most frequently used feedstuffs with a high concentration of nutrients are cereals. Apart from cereals, also by-products from industrial production are included in feed rations. Besides the nutritional value, also the price and local availability of nutrients are important criteria decisive for their utilization. Traditional by-products from industrial production include a locally and easily available intermediate product of the brewing industry – brewer's grains (DACCORD *et al.*, 1997). Fresh brewer's grains (BG) are produced as an intermediate product in beer-making after the separation of sweetwort (desugarization) from deslimed output (i.e. the suspension of grains in a water solution of extractive substances – sweetwort). They are insoluble parts of barley caryopsis endosperm with starch residues, glumes, and flakes of substances coagulated during malt fermentation (gluten flakes, other coagulated

proteins, dead yeast etc.). BG are considered a cheap source of crude protein into which up to 75% of the content of all crude protein of malting barley is transformed. The biological value of Crude protein contained in grains is high. This is given, among others, by the presence of dead organism residues, mainly yeast, which proliferated in the substrate during fermentation. Fresh BG have a high digestibility of organic matter – 64%, and they can be considered a good source of protein un-degradable in rumen, preferentially for dairy cows of specialized milk breeds (COSTA *et al.*, 1995). Grains contain 15.25% of proteins in dry matter on average. Mainly glucose and maltose are represented in fresh BG from monosaccharides and mainly hemicellulose from polysaccharides – 28.4% and cellulose – 16.8% in dry matter (LOHNERT *et al.*, 1996). The average content of lignin in brewer's grains is about 27.8% in dry matter. BG are also an important source of calcium, sodium, potassium, magnesium, aluminium, iron, copper, zinc, phosphorus, and sulphur (MUSSATTO and ROBERTO, 2006). Its appropriate inclusion in feed has a positive effect on increasing the efficiency and quality of milk – the content of fat, proteins and casein (GOLECKY, 2004). Another suitable source of nutrients for livestock is maize draff (AMG) produced in the process of maize starch production (BATAJOO and SHAVER, 1998). It is a by-product produced after the grinding, washing and steeping of maize grain in water while adding sulphuric acid. The principle of solubility and insolubility, different specific weight and size of individual fractions contained in maize grain processed in this way causes separation and, by the subsequent filtration, separating starch and draff, i.e. residues of the endosperm and glumes of maize grains. AMG is a suitable feed for livestock as it has a high value of ruminal degradability of dry matter – 56.9%, crude protein – 70.3% (BATAJOO and SHAVER, 1998).

The aim of the submitted thesis was to identify differences between the ruminal degradability and intestinal digestibility of crude protein contained in fresh BG and fresh AMG.

MATERIAL AND METHODS

The submitted thesis assessed the ruminal degradability and intestinal digestibility of crude protein in samples of fresh BG and fresh AMG. The effectiveness of ruminal degradability was tested using the "in sacco" method on 3 dry Holstain cows fitted with rumen cannulas. The cows were fed twice a day at 6 a.m. and 4 p.m. The feed ration was comprised of 4 kg of lucerne hay, 10 kg of maize silage and 1 kg of a mixture of barley meal with mineral and vitamin supplements. The samples of BG and AMG were dried at 60 °C for a period of 24 hours and then milled in a laboratory mill with a 1mm sieve. The contents of dry matter, crude protein, fibre and ash matter (ANONYM, 2001), and neutral detergent fibre (ISO 16472, 2009) were determined for the samples taken. According to TŘÍNÁCTÝ *et al.* (2009), the acquired samples were put, in the amount of 2 g of dry matter, in nylon bags 90 x 150 mm, i.e. 15 mg/cm^2 of the bag area with pore size 42 µm (VAZANT *et al.*, 1998), and these fixed into a cylindrical carrier. The nylon bags with samples were incubated in the rumens of cannulated dairy cows standing dry for periods of 2, 4, 8, 16, and 24 hours. The effective ruminal degradability was calculated using the method according to ØRSKOV and McDONALD (1979) at the anticipated rate of rumen content passage 6% per hour. The intestinal digestibility of crude protein undegradable in the rumen was determined using the technique "mobile bag" according to HOMOLKA *et al.* (1996) on 3 dry Holstain cows fitted with intestinal cannulas. The cows were fed twice a day at 6 a.m. and 4 p.m. The feed ration was comprised of 4 kg of lucerne hay, 10 kg of maize silage and 1 kg of a mixture of barley meal with mineral and vitamin supplements. The samples of undegradable spent grains acquired after its 16-hour incubation in the rumens of dairy cows were placed in a solution of pepsin and hydrochloric acid (0,1 N solution) in an artificial maw. After 2.5 hours of incubation, they were inserted in the duodenums of 3 cannulated dry Holstain cows, 20 bags to each of them. The bags with samples found after 24 hours from insertion in the duodenums in the faeces of the cannulated dairy cows were washed 30 minnutes in water, weighted, dried (lyophilized) and their contents were combined. Then the content of dry matter and nitrogen was determined for the composite samples (ANONYM, 2001). The measured values of ruminal degradability and the calculated values of effective ruminal degradability and intestinal digestibility were tested using a two-factor variance analysis by using the Scheffe correction method against exceeding the total experimental error in the program STATISTICA 6 (2001).

RESULTS

Tab. I shows the content of selected nutrients of fresh brewer's grains (BG) and maize draff (AMG) used in determining degradability and digestibility.

The average values of the degradation level of crude protein in the two assessed feedstuffs are shown in Tab. II.

The difference between the percentages of degraded crude protein of brewer's grains after 4 hours of incubation in the rumen (18.16%) against the percentage of degraded crude protein after 2 hours of incubation (4.06%) is highly significant ($P < 0.01$). The rate of degradation of crude protein of brewer's grain (Tab. II) during its incubation in the rumen is characterized by statistically highly significant differences ($P < 0.01$) in the percentages of degraded crude protein out of their total amount in 100% dry matter between individual measurements at the monitored intervals. In the case of the AMG samples (Tab. II), a highly

I: *Dry matter content and nutritional value of fresh BG and AMG*

Nutrient	Fresh grains/draff	
	BG[1)]	AMG[2)]
Dry matter (g.kg^{-1})	278.8	401.3
	Nutrient content on a dry matter basis (g.kg^{-1})	
Crude protein	256.9	231.5
Fat	101.6	16.7
Fibre	204.5	105.0
NDF[3)]	687.0	449.1
Ash	50.8	73.0
Starch	25.5	79.5

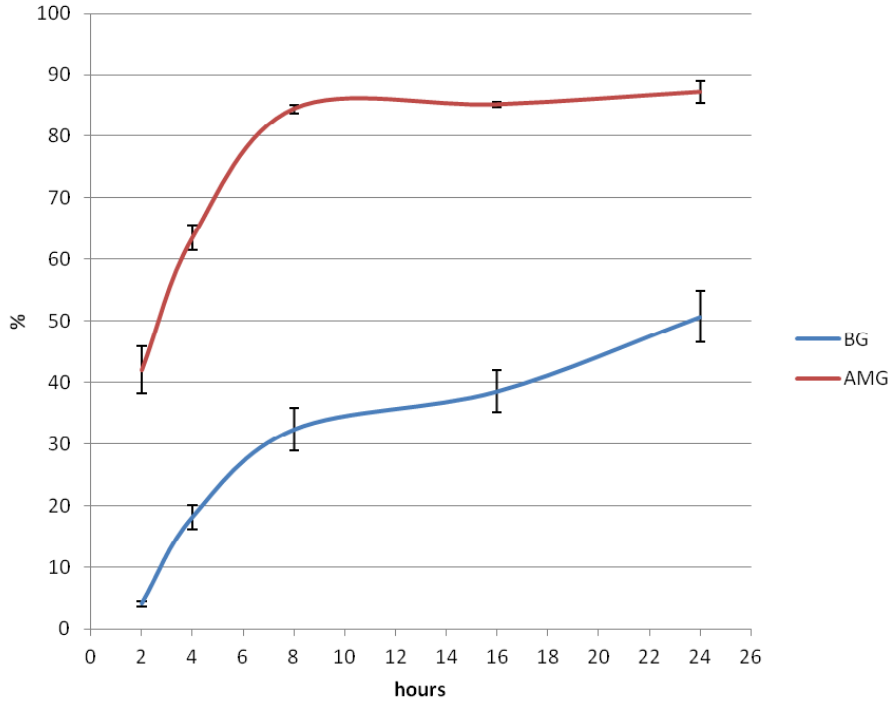
1) BG – brewer's grains
2) AMG – maize draff
3) NDF – neutral detergent fibre

significant difference (P < 0.01) was found between the amount of degraded crude protein after two hours of incubation (42.04 %) and after four hours of incubation (63.56 %); similarly, a highly significant difference (P < 0.01) was detected between the amount of degraded crude protein after four hours of incubation (63.56 %) and eight hours of incubation (84.47 %), and the amount of degraded crude protein after eight hours of incubation was twice as great as after two hours (42.04 %). The degradation of crude protein in AMG considerably decreased after eight hours (Tab. II, Fig. 1) in such a way that after 16 hours of incubation (85.1 %) the amount of degraded crude protein increased statistically nonsignificantly (P < 0.05) only by 0.69 %. A significant difference (P < 0.05) in the amount of degraded crude protein after eight hours of incubation of samples in the rumen (84.47 %) was found as late as after twenty-four hours of incubation (87.19 %).

II: *Average values of ruminal degradability of crude protein in BG and AMG in dependence on the period of ruminal incubation (%)*

Ruminal incubation period (hours)	Ruminal degradability (%)			
	Fresh BG		Fresh AMG	
	$\bar{x}$	s_x	$\bar{x}$	s_x
2	A[1] 4.06	0.48	a 42.04	3.84
4	B 18.16	1.91	b 63.56	2.05
8	C 32.40	3.54	c 84.47	0.68
16	D 38.56	3.42	cd 85.16	0.42
24	E 50.70	4.16	d 87.19	1.77

1) The averages of the same order marked with different letters are significant different (P < 0.05) – comparison of time intervals in identical feed (in BG a highly significant difference P < 0.01, in AMG a significant difference P < 0.05)



1: *The course of ruminal degradability of Crude protein in BG and AMG in dependence on the period of ruminal incubation – comparisons of feedstuffs at identical incubation time are highly signifficant diffrent (P < 0.01)*

At identical intervals of ruminal incubation, the differences in the amounts of degraded crude protein between brewer's grains and AMG (Fig. 1) were highly significant ($P < 0.01$).

The effective ruminal degradability of crude protein was calculated using the method by ØRSKOV and McDONALD (1979) at different rates of passage – 4%, 5%, 6%, 7%, and 8% of feed particles from the rumen per hour. Tab. III shows an overview of average values of effective ruminal degradability in both feedstuffs. Effective ruminal degradabilities of soluble and insoluble fractions of crude protein in BG and AMG are shown in Tab. IV.

The intestinal digestibility of crude protein and dry matter of brewer's grains and AMG are shown in Table V. The average intestinal digestibility of crude protein and dry matter of BG was 79.39% and 22.86% and AMG 56.99% and 11.34%.

III: *Effective ruminal degradabilities of crude protein at different outlet rates of rumen content*

Outlet rate [1]		Effective ruminal degradability (%)	
		BG	AMG
0.04	hour^{-1}	39.73 a[2]	79.43 b
0.05		37.35 a	77.80 b
0.06		35.33 a	76.29 b
0.07		33.60 a	74.84 b
0.08		32.10 a	73.44 b

1) Passage rate of feed particles from the rumen.
2) The averages of the same order marked with different letters are significantly different – comparison of feedstuffs at the same outlet rate ($P < 0.05$).

IV: *Parameters of effective ruminal degradability*

Parameter	Units	Effective ruminal degradability (%)	
		BG	AMG
Parameter *a*	%	4.31 b	41.53 a
Parameter *b*	%	53.52 a	45.44 b
Parameter *c*	%.h^{-1}	0.10	1.08
Parameter *lt*	h	0.62 b	3.06 a

Parameter *a* – soluble fraction, parameter *b* – potentially degradable fraction, parameter *c* – rate of fraction *b* degradation, *lt* – lag phase, scripts *a, b* – statistically significant difference in values between feedstuffs ($P < 0.05$)

V: *Intestinal digestibility of crude protein and dry matter of BG (%) and AMG (%)*

Indicator	Intestinal digestibility (%)	
	BG	AMG
Dry mater	22.86 ± 1.392 A	11.34 ± 1.376 B
Crude protein	79.39 ± 0.443 A	56.99 ± 0.730 B

Scripts A,B mean in the same row followed by different superscripts highly signifficant differ ($P < 0.01$).

DISCUSSION

The nutritional value of food industry by-products is preferentially affected by the technology used in the manufacturing of a particular food product. When making wort (malting barley) and maize starch (maize grain), the starch content in particular is significantly decreased in starting materials during the technological process. The comparison of nutrient content in the assessed BG and AMG (Tab. I) with the average nutrient content in starting materials (ZEMAN *et al.*, 1995, Tab. VI) has shown that the relative content of starch in dry matter during processing decreased from 63.96% to 2.55% and from 70.78% to 7.95%. This subsequently affected also the relative percentage of other nutrients in the dry matter of assessed food industry by-products. The content of crude protein in the dry matter of malting barely increased during the technological process of wort-making from 13.5% to 25.69% (in the dry matter of spent grains). This was caused by the above-mentioned loss of starch in the dry matter of malting barley in the process of fermentation and by the presence of dead microorganism residues in the spent grains, mainly yeast (DACCORD *et al.*, 1997). A similar trend was also observed in AMG, in which the content of crude protein in the dry matter of maize grain increased relatively from 10.3 to 23.15% in the dry matter of AMG, which again relates to starch extraction from maize grain during its processing. Similar dynamics were also recorded in the content of fibre in brewer's grains and AMG. Compared to malting barley and maize grain, the fibre content increased from 5.01% to 20.45% and from 2.67% to 10.5%.

VI: *Nutrition value of selected feedstuffs (ZEMAN et al., 1995)*

Nutrient	Feed			
	Spring barley	Industrial maize	Lucerne granules	Soybean meal
	Nutrient content in dry matter (%)			
Crude protein	13.5	10.43	17.0	54.0
Fat	2.5	4.19	3.0	1.0
Fibre	5.01	2.67	30.5	7.0
Starch	63.96	70.78	4.18	6.78
Organic matter	97.5	98.5	88.5	93.0
Ash	2.5	1.5	11.5	7.0

The optimum nutrition of high-producing dairy cows is based on the precise balancing of feed ration. Dairy cows, especially during the first phase of lactation, have high demands for providing the entire spectrum of nutrients. In such a period, they have specific demands not only for the amount of the necessary nutrients, but also for their composition (quality). This relates, among other things, to the demands for providing crude protein. In relation to the required structure of crude protein, it is necessary to meet the requirement of high-producing dairy cows by both bulky and grain feedstuffs (BOUŠKA *et al.*, 2006). Feedstuffs that are used to increase the concentration of crude protein in relation to their content in the feed ration include, traditionally, soybean meal and lucerne granules. As already mentioned, the importance of food industry by-products as components of feed rations for dairy cows has been increasing significantly in recent times. This is not only from the economic point of view, but also in relation to their nutrition value. The comparison of crude protein concentration in the dry matter of BG and AMG (25.69% and 23.15%, Tab. I) with selected traditional feedstuffs of protein character (lucerne granules and soybean meal) show that the concentration of crude protein in spent grains is significantly higher than in lucerne granules (ZEMAN *et al.*, 1995). However, it is also apparent that in relation to the content of crude protein it can in no way compete with soybean meal.

Considering the possibility of including these products in the feed rations of high-producing dairy cows it is necessary to assess, apart from the content of crude protein, also the content of fibre contained in them. In this respect, BG incline rather to lucerne granules (20.45% compared to 30.50%) and AMG to soybean meal (10.50% compared to 7.00 %). The above-mentioned comparison shows that by including BG and AMG in the feed ration of high-producing dairy cows, the concentration of crude protein content can be achieved, but with a significantly lower effect than by including soybean meal. However, including BG in the feed ration does not cause a significant decrease in the content of crude fibre.

When optimizing the nutrition value of feed ration it is necessary to follow not only the content of nutrients in feed ration, but also the body's ability to utilize the administered nutrients to the maximum, i.e. to degrade and absorb them in due time. To secure the maximum sign of the genetic potential of high-producing dairy cows it is important, among other things, to provide the appropriate percentage of undegradable crude protein out of their total amount. The mutual comparison of degradability of crude protein contained in BG and AMG (Tab. II) shows that crude protein contained in brewer's grains had significantly lower degradability ($P < 0.01$) compared to crude protein contained in AMG during the entire period of incubation. And at the early stage of incubation (after 2 hours) the difference was much greater (4.06% compared to 42.04%) than at the final stage of incubation (after 24 hours – 50.7% compared to 87.19 %). With regard to the fact that the content of crude protein in the dry matter of brewer grains (25.69%) and AMG (23.15%) was at approximately the same level, it can be stated that during the first two hours of their incubation in the rumen 10 times more, and after 24 hours, 1.7 times more crude protein were degraded in the rumen from the AMG samples than from the brewer's grain samples. The difference in the level of degradation of crude protein in both feedstuffs and its course at individual time intervals is characterized in Fig. 1. The level of effective ruminal degradability of crude protein (Tab. III) calculated using the method according to ØRSKOV and McDONALD (1979) shows that at all calculated rates of passage of the rumen content significant differences ($P < 0.05$) were found between feedstuffs, and the effective degradability of AMG (76.29%) at the passage rate of rumen content 6% per hour was more than twice (2.16) as high as the effective degradability of BG (35.33 %). PROMKOT and WANAPAT (2003) present a similar level of effective degradability of crude protein of BG detected in cannulated multiparous Holstain cows in the amount of 40.9%; PINOSA and STEFANO (1990) state the effective degradability of crude protein of fresh BG in the amount of 40.5% and BATAJOO and SHAVER (1998) state up to 48.9%. The effective ruminal degradability of the soluble fraction of crude protein of BG was significantly lower ($P < 0.05$) than the soluble fraction of crude protein of AMG (Tab. IV). Conversely, although the effective ruminal degradability of the potentially degradable fraction of BG (53.52%) was 8.08% higher than the potentially degradable fraction of AMG (45.44 %), this difference was not significant ($P < 0.05$). A high percentage of potentially degradable fraction out of the total amount of crude protein is also presented by CHIOU *et al.* (2004). Also, the period necessary for feed hydration, its population with microflora and starting the enzyme action (lt – lag time) in BG (0.62 hours) was significantly shorter ($P < 0.05$) than in AMG (3.06 hours).

The intestinal digestibility of crude protein of brewer's grain samples (79.39%) was found to be significantly higher ($P < 0.01$) than the intestinal digestibility of crude protein of AMG (56.99 %). Likewise, PEREIRA *et al.* (1998), who determined crude protein rumen degradability by nylon bag technique in rumen fistulated wethers (8 hours rumen incubation) and crude protein intestinal digestibility by mobile nylon bag technique in duodenal fistulated wethers, presents high level of crude protein intestinal digestibility of BG ranged from 84.9% to 89.8%. Similarly, the intestinal degradability of brewer's grain dry matter (22.86%) was found to be significantly higher ($P < 0.01$) than AMG dry matter (11.34 %).

CONCLUSIONS

The aim of the thesis was to identify differences between the ruminal degradability and intestinal digestibility of crude protein contained in fresh BG and fresh AMG.

Based on the above-mentioned observations and calculations, it has been found that the effective ruminal degradability of crude protein of BG at all calculated rates of passage of the rumen content was significantly lower ($P < 0.05$) than that of crude protein of AMG, and the effective degradability of AMG (76.29%) at the rate of passage of the rumen content particles 6% per hour was more than twice (2.16) as high as that of BG (35.33 %). Furthermore, it has been found that the intestinal digestibility of crude protein of BG is significantly higher (79.39%) than that of crude protein of AMG (56.99 %). This means that, unlike maize draff, brewer's grains are a significant source of crude protein for the feed rations of high-producing dairy cows which have a deficit of undegradable crude protein digestible in the intestines.

SUMMARY

The aim of the thesis was to identify differences between the ruminal degradability and intestinal digestibility of crude protein contained in fresh BG and fresh AMG. The effectiveness of ruminal degradability was tested using the "in sacco" method on 3 black-spotted Holstein cows in the dry standing period with ruminal cannulas. The dynamics of ruminal degradability of crude protein (CP) was detected after 0, 4, 8, 16, and 24 hours of samples incubation in the rumen. Degradability of the crude protein of BG detected in the above-mentioned hours (%): 4.06; 18.16; 32.40; and 50.70; degradability of the crude protein of AMG: 42.04; 63.56; 84.47; 85.16; and 87.19. The effective ruminal degradability of crude protein of BG at the rate of passage of the rumen content 6% per hour was calculated in the amount of 35.33% and the effective ruminal degradability of AMG 76.29%. The values of intestinal digestibility of crude protein and dry matter of BG at the rate of passage of intestinal chymus 6% per hour were calculated in the amount of 79.41% and 22.84%, respectively, in the case of AMG, they were 57.01% and 11.33% respectively. The differences between the above-mentioned indicators of both feedstuffs were significant ($P < 0.05$). The results show that fresh brewer's grains have significantly higher ($P < 0.05$) intestinal digestibility of crude protein than fresh maize draff, so they are a more substantial source of crude protein digestible in the intestines.

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