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IN SITU RUMEN DEGRADABILITY AND INTESTINAL DIGESTIBILITY OF TWO DIFFERENT TYPES OF RAPESEED MEAL

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Abstract

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The rumen degradability and intestinal digestibility of rapeseed meal (RSM) produced in Bulgaria (Astra Bioplant Ltd., Slivo pole, Rousse district) and in Romania (Expur Ltd., Slobozia) was determined. Three non-lactating Jersey cows with a body weight of 436 ± 18 kg, fitted with rumen fistula and T-duodenal cannula were used. Three batches from each factory were taken in interval of 20 – 30 days in Bulgaria (RSMb-1, RSMb-2, RSMb-3) and in Romania (RSMr-1, RSMr-2, RSMr-3). RSM were incubated in the rumen for 0, 2, 4, 8, 16, 24 and 48 h in 6 replications. The effective degradability of DM was significantly lower for RSMr-3 compared to other samples ($P<0.05$). The results for rapidly degradable fraction *a* of CP for all the batches of Bulgarian RSM (26 to 30%) were significantly higher than those of Romanian RSM ($P<0.05$). The values for potentially degradable CP fraction *b* varied between 66% and 73% without any significant differences for either factories or batches ($P>0.05$). The effective degradability of CP at different outflow rates ($k=0.045$; 0.06; 0.08) for all the batches of Bulgarian RSM were approximately 4% higher than those for Romanian batches ($P<0.05$). The intestinal digestibility of DM determined by mobile bag technique was higher for RSMb-3 compared to other batches of RSM ($P<0.05$). The values for intestinal digestibility of CP varied between 74% (RSMr-1) and 80% (RSMb-2) without any significant differences ($P>0.05$). The protein digestible in intestine (PDI) at outflow rate 0.06/h according to Bulgarian feed evaluation system was 165 g/kg DM for RSMb and 171 g/kg DM for RSMr. The protein balance in the rumen (PBR) of RSM was 111 and 82 g/kg DM, respectively. There is room for improvements of protein nutritive values especially for Bulgarian RSM by improving the toasting process. The protein nutritional values reported in the present experiment could be used instead of the data published abroad for RSM.

Key words: rumen degradability; intestinal digestibility; protein nutritional value; rapeseed meal
Abbreviations: PBR – protein balance in the rumen, CF – crude fiber, CP– crude protein, DM – dry matter, ED – effective degradability, RSM – rapeseed meal, PDI – protein digestible in (small) intestine, RUP – rumen undegradable protein

Introduction

Rapeseed meal is a common protein source worldwide. Recently, it has become popular in Bulgaria, and some surrounding countries, including Romania. The increased interest in the rapeseed meal (canola meal) is due to the high quality of the protein complying with the requirements of ruminant animals (Sehu et al., 2010). Usually, its inclusion in dairy rations is limited because of the large protein degradation rate in the rumen (McKinnon et al., 1991; Bayourthe et al., 1998; Von Keyserlingk et al., 2000). Piepenbrink and Schingoethe (1998) estimated that approximately 60.5%

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of the protein in the rapeseed meal was rumen degradable. However, the residue after 12 hours of incubation in the rumen showed that the amino acid profile was similar to that of the milk proteins, which makes the addition of RSM beneficial in the rations of lactating cows (Piepenbrink and Schingoethe, 1998).

Recently, a variety of rapeseed, canola, has become the preferred type of rapeseed used in animal nutrition. The canola variety was developed by selecting rapeseed plants with low levels of erucic acid and glucosinolates (Thomas, 2005; Newkirk, 2009; Maison, 2013). Extracting oil from canola can be accomplished by solvent extraction or extrusion (Adams et al., 2006). The method of processing of rapeseed (physical or chemical) influence the degradation of the CP in the rumen, as well as the digestibility in the small intestine (Homolka et al., 2007). Normally, in Bulgaria and some other countries, the solvent extraction process is used, which should result in a product with a relatively higher rumen degradability rate. However, there is no data about the exact protein nutritional value of the RSM produced in Bulgaria. That was the main reason to carry out the present comparison between Bulgarian and imported from Romania RSM.

The aim of this study was to investigate the rumen degradability and intestinal digestibility of imported and locally produced Bulgarian rapeseed meal.

Materials and Methods

Animals and diet

The animal experiment was carried out with consistency of Bulgarian legislation in field of the animal welfare and with the respect of the Bulgarian Food Safety Agency (*License № 126 registered in BFSA*).

The animals and diet used for this experiment were the same as described in our previous article (Nedelkov et al., 2017).

Tested RSMs

Six different batches were collected from two oil-producing factories located in Bulgaria and in Romania. The individual batches from each factory were collected in an interval of at least 20 days. The Bulgarian factory was "Astra Bioplant" Ltd. in Slivo pole, district Rousse (RSMb-1, RSMb-2, RSMb-3) and a Romanian company, from which RSM is imported in Bulgaria, was located in Slobozia, "Expur" Ltd. (RSMr-1, RSMr-2, RSMr-3 – *number indicated the batch number*).

In situ procedures and mobile bag technique

The *in situ* procedures for determination of rumen degradability and mobile bag technique for intestinal digestibility were the same as that described by Nedelkov et al. (2017). The tested feeds were incubated in the rumen for 0, 2, 4, 8, 16, 24 and 48 h in 6 replications.

Chemical analysis

The chemical composition of the RSM was determined according to the AOAC (2007) (Table 1).

Calculations and Statistical analysis

The degradation kinetics of DM and CP for each feed were fitted to the equation described by Orskov & McDonald (1979), using the Marquardt algorithm for non-linear regression procedure (SPSS ver. 23, Chicago, USA).

Table 1

Chemical composition of different batches of rapeseed meal (% of DM)

Parameters	RSMb-1	RSMb-2	RSMb-3	RSMr-1	RSMr-2	RSMr-3	Mean (SD)
Dry matter, %	92.71	92.19	91.65	92.51	92.88	92.62	92.427 (0.445)
Crude protein	35.33	35.96	34.26	32.38	32.53	35.31	34.295 (1.527)
Crude fiber	12.32	11.28	12.79	12.2	11.26	9.05	11.483 (1.337)
Ether extract	3.92	3.48	3.75	2.88	3.21	3.07	3.385 (0.403)
Nitrogen – free extracts	41.04	41.7	41.96	45.06	45.84	45.23	43.472 (2.124)
Crude ash	7.39	7.58	7.24	7.48	7.16	7.34	7.365 (0.154)
Ca	0.86	0.75	0.79	0.84	0.81	0.76	0.802 (0.044)
P	1.24	1.28	1.15	1.10	1.05	1.16	1.163 (0.085)

The Effective degradability (ED) of tested feeds was calculated using assumed outflow rates *(k)* of 0.045, 0.06 and 0.08 h^{-1}.

The values for protein truly digestible in small Intestine (PDI) and protein balance in the rumen (PBR) were calculated according to the Bulgarian protein system (Todorov et al. 2007) by the following equations:

PDI = *1.11*CP(1 – ED)* IDRUP + 0.093*FOM + 4*

PBR= *CP*(ED – 0.1) – 0.145*FOM*

Where *IDRUP* is the intestinal digestibility of rumen undegraded protein (as part of 1), *FOM* is the fermented organic matter (g/kg RSM) and *ED* is effective degradability (as part of 1). FOM for calculation of PDI and PBR was taken from Todorov et al. (2007)

The data were subjected to the analysis of variance (ANOVA) using the SPSS Program (Version 23). The significance was declared at $P < 0.05$.

Results and Discussion

Degradation parameters of DM

The values for the rapidly degradable fraction *a* of the DM of RSM varied from 20.03% at RSMr-3 to 26.93% at RSMr-1 (P<0.05) (Table 2). In the studies of Woods et al. (2003), this value was an average of 27.16%. At five different sources of rapeseed meal, Mustafa (1996) found that the rapidly degradable DM fraction *a* can vary from 17.02% to 26.02%. Such variations were also observed at the potentially degradable DM fraction *b* wherein the results ranged from 53.71% (RSMr-1) to 68.11% (RSMb-2). Other authors (Mustafa, 1996; Homolka et al., 2007) established identical differences in the DM degradation parameters.

The ED of DM at the third batch of the Romanian RSMr-3 was 56.54% at 0.045/h and 47.46% at 0.08/h, differing significantly compared to all other samples (P<0.05). Sehu et al. (2010) also found that the DM effective degradability of RSM was approximately 50% at rumen passage rate 0.06/h.

Degradation parameters of CP

It is noteworthy to mention that the soluble fraction *a* of CP in all three batches of Bulgarian RSM (29.31%, 29.89% and 26.03%) was significantly higher compared to the Romanian batches (Table 3). Mustafa et al. (2000) reported similar results for the washable CP fraction *a* in their *in situ* study for rumen degradation of canola meal. Homolka et al. (2007) and Todorov et al. (2016) reported even lower (15% – 16%) values for rapidly degradable CP fraction *a* of Romanian RSM. However, statistical differences between Bulgarian and Romanian RSM in terms of potentially soluble fraction *b* of the CP were not established and the values were within ranges of 66.38% (RSMb-1) to 72.71% (RSMr-3).

Table 2

Dry matter degradation parameters and effective degradability of dry matter of different batches of rapeseed meal at different outflow rates (k=% h^{-1})

Rapeseed meal	a, %	b, %	c (h^{-1})	Effective degradability of DM		
				k=0.045	k=0.06	k=0.08
RSMb-1	23.28^{ab}	65.82^{a}	0.052^{b}	58.69^{a}	53.97^{a}	49.33^{a}
RSMb-2	26.61^{a}	68.11^{a}	0.042^{b}	59.61^{a}	54.77^{a}	50.17^{a}
RSMb-3	25.44^{a}	65.18^{a}	0.053^{b}	60.63^{a}	55.71^{a}	51.07^{a}
RSMr-1	26.93^{a}	53.71^{b}	0.061^{a}	57.77^{a}	53.94^{a}	50.1^{a}
RSMr-2	24.97^{a}	57.09^{ab}	0.063^{a}	58.32^{a}	54.26^{a}	50.17^{a}
RSMr-3	20.03^{b}	63.53^{a}	0.061^{a}	56.54^{b}	52.06^{a}	47.46^{b}

$^{a-d}$ Means within a column lacking common superscript differ significantly at P<0.05

Table 3

Crude protein degradation parameters and effective degradability of crude protein of different batches of rapeseed meal at different outflow rates (% h^{-1})

Feeds	a, %	b, %	c (h^{-1})	Effective degradability of CP		
				k=0.045	k=0.06	k=0.08
RSMb-1	29.31^{a}	66.38^{a}	0.079^{a}	71.61^{a}	67.05^{a}	62.31^{a}
RSMb-2	29.89^{a}	69.75^{a}	0.062^{b}	70.27^{a}	65.29^{a}	60.34^{a}
RSMb-3	26.03^{a}	72.94^{a}	0.068^{b}	69.64^{a}	64.56^{a}	59.37^{a}
RSMr-1	20.38^{b}	71.31^{a}	0.072^{b}	64.27^{b}	59.28^{b}	54.17^{b}
RSMr-2	20.99^{b}	72.45^{a}	0.069^{b}	64.83^{b}	59.73^{b}	54.53^{b}
RSMr-3	21.72^{b}	72.71^{a}	0.070^{b}	65.92^{b}	60.81^{b}	55.59^{b}

$^{a-d}$ Means within a column lacking common superscript differ significantly at P<0.05

Table 4
Dry matter and crude protein intestinal digestibility of the residue of rapeseed meal after 16 h of rumen incubation

Parameters	RSMb-1	RSMb-2	RSMb-3	RSMr-1	RSMr-2	RSMr-3
Intestinal digestibility of rumen undegraded DM, %	41.13[b]	46.83[ab]	50.49[a]	43.84[ab]	45.31[b]	43.39[b]
Intestinal digestibility of rumen undegraded CP, %	78.89[a]	80.16[a]	80.81[a]	74.14[a]	76.19[a]	77.79[a]

[a–b] Means within a row lacking common superscript differ significantly at P<0.05

The results obtained for the effective degradability of CP of RSM produced in Bulgaria were 4 to 8% higher compared to the batches from Romania. Investigating the effective rumen degradability of RSM obtained through chemical extraction, Harazim et al. (2002) and Homolka et al. (2007) established values similar to our results for RSM produced in Romania. On the other hand, Masoero et al. (1994) reported lower degradation rate at two different batches of RSM – 48.35% and 57.69% respectively, but at their experiment, the rumen passage rate was not mentioned. The reported deviations could be a result of the different outflow rates, as well as the different size of grinding of the feed (Homolka et al., 2007). The degradation rate could be influenced by different technological regimes during the processing of the rapeseed, such as the higher temperature could increase the amount of proteins bounded to fibers in the feeds of plant origin, which in turn could reduce the nitrogen available for microorganisms in the rumen (Kendall et al., 1991).

In the past, it was considered that rapidly degradable fraction *a* of CP is degraded almost completely in the rumen and since a large part of the protein in RSM is easy degradable, it was thought that it is not a good source of rumen undegredable protein. Evans et al. (2016) found that the degree of degradation of fraction *a* of CP was different in feeds. For example, in RSM, only 40% of the rapidly degradable fraction *a* degraded in the rumen and the greater part of fraction *a* would pass into the small intestine as a part of the protein digested in intestine from feed origin (Bach et al., 2008).

Intestinal digestibility of DM and CP

The lowest DM degradability (41.13%) was found in the first batch of the Bulgarian RSMb-1 (Table 4). In respect of the CP intestinal digestibility the values ranged from 74.14% (RSMr-1) to 80.16% (RSMb-3), but significant differences were not found. Demarquilly et al. (1989) and Zeman et al. (1995) also reported a high rate of the CP intestinal digestibility of RSM, which reached 80 and 75%, respectively. Boila & Ingalls (1994) found that even 90% of the CP in RSM was digested in the small intestine. Contrary, Homolka et al. (2007) observed a lower value (65.3%) for the intestinal digestibility of CP in RSM. The observed variations could have been due to the different size of both the bags and the pores of the fabric used for making the bags in individual experiments. Homolka et al. (2007) emphasized that the various processing methods also influenced the rumen degradability and intestinal digestibility of RSM.

Calculation of Protein Digestible in Intestine (PDI) and protein balance in the rumen (PBR) values

The mean values for PDI (Table 5) obtained at the present study are in accordance with the data summarized in the Handbook of Animal Nutrition (Todorov et al., 2007). Though, significant differences were found among individual sources of RSM, as the PDI for RSMb-1 was lowest and RSMr-3 was highest at an average rumen passage rate of 0.06/h (P<0.05). However, the values for PBR calculated using the results for the effective degradability and intestinal digestibility in the present experiment, were much higher than the data published

Table 5
PDI and PBR values of 1 kg dry matter of rapeseed meals calculated at different outflow rates (k = % h^{-1})

Feedstuffs	PDI			PBR		
Outflow rates	k = 0.045	k = 0.06*	k = 0.08	k = 0.045	k = 0.06*	k = 0.08
RSMb-1	146[b]	160[b]	175[c]	133[a]	117[a]	100[a]
RSMb-2	153[ab]	169[ab]	185[b]	132[a]	114[a]	97[a]
RSMb-3	151[ab]	167[ab]	183[b]	119[b]	103[b]	85[b]
RSMr-1	153[ab]	167[ab]	180[bc]	91[c]	75[c]	59[c]
RSMr-2	155[ab]	169[ab]	183[b]	94[c]	77[c]	60[c]
RSMr-3	162[a]	178[a]	194[a]	113[b]	95[b]	77[b]
Average	153	168	183	114	97	80
Todorov et al. 2007		164			151	

[a–c] Means within a column lacking common superscript differ significantly at P<0.05

* PDI and PBR values were calculated using the data for FOM (Fermented organic matter) published by Todorov et al.(2007)

by Todorov et al. (2007). The observed variations could be a result of both differences in processing methods and the nutritional characteristic of rapeseed, as there are also seasonal variations and some environmental factors that could influence the nutrient content of the raw material.

Conclusions

A significant difference was observed in some of the protein nutritional characteristics (PDI and PBR) between the imported Romanian and locally produced Bulgarian RSM. There is some room to increase the protein nutritive values, especially for Bulgarian RSM, by applying the proper toasting process. The protein nutritional values reported in the present experiment could be used instead of the data published abroad for RSM.

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