Ruminal Degradability and Intestinal Digestibility of Dm and Cp in High-Protein Fraction from Sunflower Meal - A Cheap Source of Dietary Protein for Ruminants

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Research Article

Ruminal Degradability and Intestinal Digestibility of Dm and Cp in High-Protein Fraction from Sunflower Meal - A Cheap Source of Dietary Protein for Ruminants

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Abstract | The objective of this study was to evaluate the ruminal degradability and intestinal digestibility of high protein fraction from sunflower meal (HPSFM). Three non-lactating Jersey cows with an average body weight of 436 ± 18 kg, fitted with a fistula in the dorsal rumen and a T-duodenal cannula were used to estimate rumen degradability and intestinal digestibility of dry matter (DM) and crude protein (CP). The HPSFM was produced by mechanical processing of sunflower meal. Five samples (HPSFM1 to HPSFM5) from different batches produced in interval of 20 days were collected and incubated in the rumen for 0, 2, 4, 8, 16, 24, and 48 h in 6 replications. The values for the rapidly degradable fraction *a* of DM ranged from 212 to 238 (SD = 9.15) g/kg. The effective degradability of DM of HPSFM at rumen outflow rate of 0.06/h ranged from 635 to 706 (SD = 28.7) g/kg. The fraction *a* of CP of the high protein sunflower meal samples was within the ranges from 167 to 197 (SD = 12.6) g/kg. Effective degradability of HPSFM CP at rumen outflow rate of 0.06/h was relatively high and varied from 661 to 730 g/kg (SD = 23.6). The intestinal digestibility of the DM measured by mobile bag technique ranged from 489 to 552 (SD = 22.1) g/kg. The intestinal digestibility of CP was relatively high and averaged 945 g/kg, varying from 939 to 954 (SD = 5.23) g/kg. The average value for Protein Digestible in the small Intestine (PDI) according to the Bulgarian protein system (assuming 618 g of rumen fermentable organic matter from a well dehulled sunflower meal), and a rumen outflow rate of 0.06/h was 205 (SD = 13.2) g/kg DM, while the Rumen Protein Balance (RPB) was 187 (SD = 9.52) g/kg DM, respectively. The results of the present study could be used in formulating rations for ruminant animals. HPSFM may effectively replace the expensive soybean meal in cow/calf diets and reduce costs in the feedlot, thus it will greatly improve the profitability of the beef cattle industry. The data shows possibilities for improvement of the protein value of HPSFM by applying stem-heating toasting or other effective technologies for decreasing degradability in the rumen.

Keywords | Rumen degradability, Intestinal digestibility, Protein nutritive value, Sunflower meal

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INTRODUCTION

Sunflower meal (SFM) is a basic and cheap source of feed protein in Bulgaria. There are several advantages of SFM compared to other protein feeds, such as comparatively low price, high content of sulfur-containing amino acids methionine, cystine, and cysteine, and low content of anti-nutritional factors. However, its use in ruminant's diets is usually limited because of its high rumen degradability (Bautista et al., 1990). According to Mondal et al. (2008) rumen CP degradability of SFM at 0.06/h outflow rate was 56%, while Chrencova et al. (2010), Diaz-RoyoNr et al. (2016) and Nedelkov (2019) reported degradability ranging from 70% to 85%. Another serious constraint

for the rational use of SFM in ruminant nutrition is the higher hulls/fiber content, which decreases both its energy and protein value. Different mechanical means were tested for lowering its fiber content including milling, sifting out, and blowing off the SFM (LePrince-Bernard, 1990; Levic et al. 1992; Grompone, 2006; Banjac et al. 2013), double dehulling (Cortamira et al., 2000), centrifugal separation of hulls (Yadav et al., 1996; Sredanovic et al., 2011) and freezing by liquid nitrogen followed by heating to separate hulls from the kernel (Lange et al., 1984). Recently, a new method/technology for the separation of SFM into two fractions was developed in Bulgaria (Draganov, 2015). By repeatedly application of rolling, sifting and blowing, the SFM was split into low and high protein fractions. The high-protein fraction from sunflower meal (HPSFM) contains only 5 – 8% crude fiber and 46 – 50% crude protein while the low-protein fraction contains 36 – 55% crude fiber and 17 – 23% protein. However, there are no data available about the exact protein nutritional value for ruminants of the HPSFM which was the main reason to carry out the present research.

Thus, the objective of this study was to evaluate the ruminal degradability and intestinal digestibility of HPSFM and further estimate its protein feeding value in terms of protein truly digestible in the small intestine. We hypothesized that the additional dehulling of SFM will significantly improve its nutritional value.

MATERIALS AND METHODS

Animals and samples

The animal experiment was carried out according to the Bulgarian legislation in field of the animal welfare and with the respect of the Bulgarian Food Safety Agency (*Registration license № 126)*.

Three non-lactating Jersey cows with an average body weight of 436 ± 18 kg, fitted with a rumen (made from polycarbonate material with internal diameter = 12 cm) and T-shape duodenal cannula (polycarbonate material with internal diameter = 4.4 cm) were used in the experiment. During the adaptation (10 d) and experimental (15 d) periods, cows were fed at maintenance level a ration containing 800 g/kg roughages (63.6 % alfalfa hay and 16.4% barley straw) and 200 g/kg concentrate (30.5% ground corn grain, 26.5% ground barley grain, 23.0% wheat bran, 17.0% SFM and 3% mineral and vitamin premix). Cows were housed in the large ruminant facility of Trakia University's Research Center, Faculty of Veterinary Medicine (42°25'27"N 25°36'28"E), and were fed at approximately 8.00 h and 16.00 h. Feeding was ad libitum targeting 5% refusals.

High-protein sunflower meal samples were collected from the first company which implemented the new technology for mechanical processing of sunflower meal - Bonmix Ltd., Lovech, Bulgaria (HPSFM1 to HPSFM5, numbers indicate the individual batch). The individual batches were collected in an interval of at least 20 days.

Briefly, samples (approximately 2.5 g) of each batch of SFM were placed in a polyester Dacron bags, which were later incubated in the rumen of the cows for 0, 2, 4, 8, 16, 24 and 48 h in duplicates (i.e., a total of 6 bags per incubation time-point). Then, the bags were dried at 65°C for 48 h and DM content of the residue was determined by drying at 105°C for 2 h in a mechanical convection oven. Intestinal digestibility of HPSFM DM and CP was analyzed by the mobile bag technique following the procedure of Woods et al. (2003b). A full description of the *in situ* rumen incubation and estimation of the small intestinal digestibility of ruminal-undegraded fraction can be found in Nedelkov (2019).

Chemical analysis

High-protein sunflower meal samples obtained from the factory were finely ground (to pass through a 1-mm screen). Dried samples were analyzed by wet chemistry methods EE (method 2003.05; AOAC International, 2006), ash (method 942.05; AOAC International, 2000), and minerals (method 985.01; AOAC International, 2000) (Table 1). Sunflower meal samples and bag residues were analyzed for N (Kjeltec™ 8400 Analyzer Unit, FOSS, DK-3400 Hillerod, Denmark) and CP was calculated as N × 6.25.

Calculations and Statistical analysis

Ruminal DM and CP degradation data were fitted to the exponential equation of Orskov & McDonald (1979), using the Marquardt algorithm for non-linear regression procedure (SPSS ver. 23, Chicago, USA).

$$d = a + b\,(1 - \exp(-^{c\,t})$$

Where *d* is degradability (g/kg) at time *t*, *a* is the soluble and rapidly degradable fraction of DM or CP, *b* is the potentially degradable fraction, *c* is the rate of degradation of fraction *b*, and *t* is the incubation time (h).

Effective degradability (ED) of DM and CP were calculated using the following equation (AFRC, 1993):

$$ED = a + (b \times c)/(c + kp)$$

Where *a*, *b*, and *c* are as specified above and *kp* is the passage rate, assumed at 0.05, 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 (Todor

Table 1: Dry matter content and chemical composition (g/kg dry matter or as indicated) of high-protein sunflower meal samples used in the study.

Parameters	Average	Minimum	Maximum	SD	CV, %
Dry matter, g/kg	928	917	936	8.21	0.88
Crude protein	459	452	467	5.03	1.09
Ether extract	19.6	11.2	29.5	6.51	33.2
Ash	89.3	86.6	92.3	1.88	2.11
Ca	6.12	5.21	6.73	0.52	8.48
P	13.3	10.3	17.1	1.17	6.98

Table 2: Ruminal degradation parameters and effective degradability of dry matter of high-protein sunflower meal (HPSFM) samples (g/kg, or as specified).

Parameter	Average[a]	Minimum	Maximum	SD	CV, %
a,[b]	229	212	238	9.15	3.99
b,[b]	713	680	776	33.5	4.70
c[b]/h^{-1}	0.113	0.073	0.131	0.02	18.8
kp[c] = 0.045/h^{-1}	731	689	759	23.9	3.27
kp = 0.06/h^{-1}	687	635	706	28.7	4.18
kp = 0.08/h^{-1}	638	579	659	32.3	5.06

[a] $P < 0.01$ for the main effect of HPSFM sample.
[b] a, b, and c are soluble, potentially degradable fraction and rate of degradation of fraction *b*, respectively;
[c] kp is the passage rate from the rumen;
N = 30.

Table 3: Ruminal degradation parameters and effective degradability of crude protein of high-protein sunflower meal (HPSFM) samples (g/kg, or as specified).

Parameters	Average[a]	Minimum	Maximum	SD	CV, %
a,[b]	188	167	197	12.6	6.68
b,[b]	790	779	826	17.9	2.27
c[b]/h^{-1}	0.114	0.089	0.127	0.014	12.3
kp[c] = 0.045/h^{-1}	751	716	776	20.3	2.70
kp = 0.06/h^{-1}	702	661	730	23.6	3.36
kp = 0.08/h^{-1}	649	602	679	26.3	4.06

[a] $P < 0.01$ for the main effect of HPSFM sample.
[b] a, b, and c are soluble, potentially degradable fraction and rate of degradation of fraction *b*, respectively;
[c] kp is the passage rate from the rumen;
N = 30

ov et al. 2007).

Data were analyzed for the fixed effect of different batches of protein source using the GLIMMIX procedure of SAS (2002-2012; SAS Institute Inc., Cary, NC). Significance was declared at $P < 0.05$. Means are expressed as least squares means.

RESULTS AND DISCUSSION

Chemical composition of SFM

The average CP content of HPSFM was 459 (SD = 5.03) g/kg, ranging from 452 g/kg DM to 467 g/kg (Table 1). The CP content of commercial sunflower meal produced after an average degree of dehulling of the seeds varied from 345 g/kg (Todorov et al., 2007) to 369 g/kg (Nedelkov, 2019). The production technology for HPSFM allows enrichment of the sunflower meal protein, thus it might be a serious and sustainable alternative to soybean meal on the European feed market.

Rumen degradability of DM and CP

The DM and CP ruminal degradation parameters and effective degradability values at different outflow rates are presented in Tables 2 and 3. The mean value for the rapidly degradable fraction *a* of DM was 229 g/kg and varied

Table 4: Dry matter and crude protein intestinal digestibility (g/kg) of high- protein sunflower meal (HPSFM) samples following a 16-h rumen incubation.

Parameter	Average[a]	Minimum	Maximum	SD	CV, %
Intestinal digestibility of RUDM[b]	519	489	552	22.1	4.25
Intestinal digestibility of RUCP[c]	945	939	954	5.23	0.55

[a] $P < 0.01$ for the main effect of HPSFM sample.
[b] RUDM – Ruminally-undegraded dry matter
[c] RUCP – Ruminally-undegraded crude protein

Table 5: Protein digestible in intestine (PDI) and rumen protein balance values (RPB) of 1 kg dry matter of high-protein fraction of sunflower meals (HPSFM) calculated at different outflow rates (g/kg).

Parameter	Average[a]	Minimum	Maximum	SD	CV, %
PDI					
kp[b] = 0.045/h^{-1}	182	167	201	11.3	6.23
kp = 0.06/h^{-1}	205	189	228	13.2	6.42
kp = 0.08/h^{-1}	224	205	252	15.6	6.93
RPB					
kp = 0.045/h^{-1}	209	197	217	7.92	3.79
kp = 0.06/h^{-1}	187	171	196	9.52	5.09
kp = 0.08/h^{-1}	162	144	173	10.7	6.57

[a] $P < 0.01$ for the main effect of HPSFM sample.
[b] kp is the passage rate from the rumen;
N = 30.

from 212 to 238 (SD = 9.15) g/kg which is consistent with the results reported by others for washable DM fraction of common SFM (Griffiths, 2004; Alcaide et al., 2003; Gao et al., 2015). However, the average value (713 g/kg; SD = 33.5) for the nonwashable but potentially degradable fraction *b* of DM was higher compared to the data for SFM found in some previous studies (Mondal et al., 2008; Nedelkov, 2019). The difference is likely a result of the removal of a bigger proportion of the hulls which in turn decreases the lignin content, not degradable in the rumen, and thus improves energy and protein value of SFM.

The average value of effective DM degradability at mean rumen outflow rate of 0.06/h was 687 (SD = 28.7) g/kg. Expectedly, the DM degradability of HPSFM was higher than the published values for common SFM (Alcaide et al., 2003; Nedelkov, 2019). This can be associated with the presence of large quantities and high degradability of fraction *b*, resulting in low amounts of DM undegradable fraction.

The washable fraction *a* of CP ranged from 167 to 197 (SD = 12.6) g/kg, while the potentially degradable fraction *b* varied from 779 to 826 (SD = 17.9) g/kg. Thus, the estimated effective degradability of CP in HPSFM was considerably high, reaching a maximum of 776 g/kg at rumen passage rate of 0.045/h. Overall, the degradability parameters and extent of protein degradation in the rumen of HPSFM are in agreement with previously reported values for a common/original SFM samples (75.0 to 90.0%; Woods et al., 2003a; Chrenkova et al., 2010; Nedelkov, 2019). According to Broderick at al. (1988) besides its faster degradation rate, the rumen retention time of SFM is higher compared to the soybean meal. However, previous results from our team highlighted a serious decline of milk yield after replacing the HPSFM with a common SFM (34.5% CP) in the diets of highly producing dairy cows (Nedelkov et. al., 2019; unpublished results). The nutrient composition of the diets was similar among treatments, therefore we attributed the positive effect on milk yield to the faster ruminal escape of HPSFM. Because of the additional separation of SFM, the new high protein and low cellulose fraction consists of fine, tiny and light particles that may float very easily in the rumen content and leave it earlier with the liquid fraction. The size of the particle has been suggested as a key factor that affects degradation rates (Emanuele and Staples, 1988). Nevertheless, further studies by the use of specific markers are needed to confirm the above hypothesis.

Intestinal digestibility of DM and CP

The intestinal digestibility of HPSFM DM varied from 489 to 552 (SD = 25.9) g/kg (Table 4). The average intestinal digestibility of HPSFM CP was 945 g/kg and ranged from 939 to 954 (SD = 5.23) g/kg. These values are slightly higher than previously reported for the common SFM samples where intestinal digestibility of CP was reported to vary from 838 to 899 g/kg (Woods et al., 2003b;

Nedelkov, 2019). The removal of a bigger proportion of the hulls is likely to be the main reason for the improved digestibility of HPSFM previously incubated for 16 h in the rumen.

The average estimated PDI and RPB (at 0.06/h outflow rate) of the HPSFM samples estimated in the current study were 205 (SD = 13.2) g/kg and 187 (SD = 9.52) g/kg, respectively (Table 5). Overall, the PDI and RPB values of HPSFM are significantly higher compared to the values of common (not mechanically treated) SFM and closer to those reported for soybean meal (Todorov, 2007), suggesting that low cellulose fraction of sunflower meal may be a serious and cheaper alternative of expensive and mostly imported soybean meal. Considering the lower price and better protein value which is comparable to that of soybean meal, it is possible to use HPSFM as a main dietary protein source for both high-lactating dairy and fattening beef cattle. This is particularly valid for the beef production which is mainly determined by feed price and availability. Therefore reducing costs through feed inputs will result in improved profitability of the beef cattle industry.

To the best of our knowledge the ruminal degradability and intestinal digestibility parameters of HPSFM have not been previously studied, therefore the results of the present study should be used in formulating rations for ruminant animals. Even though the data showed high values of ruminal HPSFM CP degradability it can be improved by proper toasting of sunflower in processing mill or additionally by steam heating, extrusion or other effective technologies for decreasing degradability in the rumen.

CONCLUSIONS

The results of the present study could be used in formulating rations for ruminant animals. HPSFM may effectively replace the expensive soybean meal in cow/calf diets and reduce costs in the feedlot, thus it will greatly improve the profitability of beef/dairy cattle industries. The data shows some possibilities for improvement of the protein value of HPSFM by applying stem-heating toasting or other effective technologies for decreasing degradability in the rumen.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHORS CONTRIBUTION

Krum Nedelkov conceptualized the study, designed and conducted the experiment, analyzed the data and prepared the manuscript. Todor Slavov carried out the experiment, and lab-oratory analysis. Gonzalo Cantalapiedra participated in data analysis as well as drafting and revising the paper. All authors read and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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