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A new approach for processing and use of sunflower meal

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Abstract

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Sunflower meal (SFM) is a basic and cheap source of feed protein in Bulgaria. Its use is limited by the high content of hulls, which decrease its energy and protein value, and by low content of the amino acids lysine and threonine. In ruminants, an additional problem is a high degradability of protein. For more than ten years a new technology for separation of SFM in low and high cellulose fractions was developed and applied. The low cellulose fraction contains 46 or 50% crude protein (HPSFM-46 or -50). It is suitable for feeding poultry, growing pigs and lactating sows. To increase utilization of diet is necessary for SFM to be supplemented with fat, synthetic amino acids (lysine, threonine), enzymes (phithase, β-glucanase, xylanase, protease) and eventually to be pelleted. The high cellulose fraction (17% crude protein) contains too much impregnation by lignin and silica hulls, which limit including in rations. After additional removal of parts of hulls and supplementation with molasses, minerals and vitamins, it may become acceptable concentrate feed (app. 25% CP) for low productive ruminants (dry cows, first stage of fattening animals, replacing heifers, lambs, and kids). It is necessary to prove possibilities to use this low protein fraction in rations of rabbits, pregnant sows and during the finishing period of fattening pigs. SFM for high productive ruminants should be toasted to decrease degradability and increase utilization of protein. Studies are needed for better estimation of the feeding characteristics of different new SFM products, for optimizing combinations with other protein sources, and for establishing the best composition of feed mixtures for different species and categories of animal. Trials are needed for estimation of the degree of replacement of soybean meal by new SFM products and its economic impact on animal production.

Keywords: sunflower meal; advantages; processing
Abbreviations: SFM – sunflower meal; CF – crude fiber; CP – crude protein

Advantages and constraints of the sunflower meal

In Bulgaria and in Eastern Europe sunflower is the main protein-rich crop, and sunflower meal (SFM) is the most abundant and cheap high-protein feed. In Spain, France, USA, Argentina, India and China sunflower crops also occupy a significant area.

The advantages of SFM in comparison to other protein feeds are comparatively low price, high content of sulfur – containing amino acids methionine, cystine and cysteine and lack of anti-nutritional substances.

However, there are several constraints for the use of SFM as animal feed. The significant portion of hulls remaining in SFM decreases both its energy and protein values. The high content of polysaccharides (app. 30%) decreases the digestibility and utilization of SFM by poultry and pigs. The high content of lignin (6 – 12%) also contributes to decreasing digestibility and to increased fecal losses of metabolic protein. The biological value of protein is relatively low because of the deficit of amino acids lysine and threonine. The high phytate content (3 – 4% of dry matter, or 80 – 85% of phosphorus) decreases the digestibility of nutrients and utilization of phosphorus by poultry and pigs. SFM contains a significant quantity of phenols which cause changes in SFM color when moisture gets high.

The content of 17-20% soluble protein fraction (Bautista et al., 1990), and high rumen degradability decrease essentially the protein value of SFM for ruminant animals. According to Mondal et al. (2008) rumen degradability at 0.06/h outflow rate is 56%, while Freer and Dove (1984), Chrenkova et al. (2010), Diaz-Royon et al. (2016) found 80% and higher values. According to Broderick at al. (1988) besides the faster degradation of the SFM it passes through the rumen more slowly compared to soybean meal. SFM has the highest degradation rate of all basic protein meals used in animal feeding (Anderson et al., 2000).

The variation of the composition and nutritive values of sunflower meal is significant

The traditional processing methods of sunflower seeds result in significantly different feed products. Some processors don't separate hulls before extraction of oil, while others remove different parts of the hulls. There are processors applying only pressing, with the residual press cake containing 7 – 12% oil, while most of them extract the remaining oil to produce meal. Therefore, the composition and nutritive value of SFM sold to farmers or feed mills varies significantly (Table 1). Some sunflower processing mills which don't separate hulls at all, or separate only a small proportion, produce pelleted SFM to make it more acceptable as a feed. In this way it is difficult to use the published data for balancing diet, without taking into account the protein, fiber and oil content of the SFM.

Table 1. Extend of variations of some parameters of traditional sunflower meal.

Content of the hulls	18 – 40%	well dehulled – without dehulling
Crude fiber	15 – 29%	well dehulled – without dehulling
Crude protein	25 – 39%	without dehulling – well dehulled
Metabolisable energy for poultry	7.0 – 11.0 MJ/kg	well dehulled – very well dehulled
Metabolizable energy for pigs	8.7 – 11.0 MJ/kg	well dehulled – very well dehulled
Net energy for ruminants	4.2 – 6.3 MJ/kg	without dehulling – well dehulled

Possibilities to improve the nutritive value of sunflower meal

The hulls of sunflower seeds are separated completely and the kernel is used for making special products for human consumption. However, at most of the sunflower seeds, the oil is extracted after partial dehulling and the remaining by-product is used as an animal feed, in the form of expeller (cake) or meal. The hulls have some negative effect on oil quality (Kartika, 2005). However, losses of oil and small particles of kernel increase proportionally to the degree of separation of the hulls. On the other hand, a small quantity of hulls (8 – 12% of the seeds), act as drench and help mechanical extraction of oil.

During the last 60 years in Bulgaria, as well as in other countries, many attempts have been made to separate more hulls from the sunflower seeds with the aim to decrease CF and to improve the feed quality of SFM. Different mechanical means have been applied including milling, sifting out, and blowing off the SFM (LePrince-Bernard, 1990; Levic et al., 1992; Grompone, 2006; Banjac et al., 2013), double dehulling (Cortamina et al., 2000), centrifugal separation of hulls (Yadav et al., 1996; Sredanovic, 2007; Sredanovic et al., 2011), freezing by liquid nitrogen followed by heating to separate hulls from kernel (Lange et al., 1984) and others. Different methods of dehulling sunflower seeds have also been applied in attempts to prepare biological active substances (Lomascolo et al., 2012).

Many attempts to separate SFM into low- and high-cellulose fractions were made in Novi Sad University (Serbia) by milling agglomeration of kernel and hulls and centrifugal separation of the hulls. In the low cellulose fraction (about 40% of SFM), the CP content increased to 44 – 45%, CF decreased below 12%, and hulls – below 15%. The high cellulose fraction (about 60% of SFM) contains 33% crude protein. In 9 experiments carried out with broilers, it was shown that it is possible to replace 50 to 100% of the soybean meal by low cellulose SFM, depending on composition of compound feed, without reducing live weight gain and feed conversion ratio more than 6 – 8% (Levic et al., 2005).

In Bulgaria, Draganov in 2009 developed a new method to separate SFM into two fractions which was patented (Draganov, 2015). By applying rolling, sifting and blowing several times, SFM is split into low and high cellulose parts. The low cellulose fraction (70 – 72% of SFM) contains only 5 – 8% CF and 46 – 50% CP and is named high protein fraction from sunflower meal (HPSFM) – 46 or HPSFM-50. These fractions are suitable for poultry, young growing and fattening pigs, lactating sows, fishes or dogs. The high cellulose fraction (28 – 30% of processed SFM) contains 36 – 55% CF and 17 – 23% CP and is named low protein fraction from sunflower meal (LPSFM). The hulls, being impregnated by lignin and silica, are not suitable for animals' requirements. It is advisable to partly remove the hulls and to increase CP to 25% (LPSFM-25). By adding some molasses (to fix very fine particles resulting from the separation process), minerals and vitamins it might be converted into compound feed for low productive ruminants (replacement heifers, lambs, and kids, pregnant or low productive ewes and goats, dry cows etc.). For higher productive animals LPSFM-25 may be combined with some grains.

The limited number of experiments shows that the degree of rumen degradation and intestinal digestibility of protein in the new SFM products is almost the same as in the original SFM (Nedelkov et al., 2021).

The removal of a larger proportion of hulls improves energy and protein value of SFM. The digestibility of non starch polysaccharides and proteins in poultry and pigs could be improved by supplementation with some enzymes like phytase, β-glucanase, xylanase, protease and others. It is possible for the biological value of SFM to be increased by supplementation with the amino acids lysine and threonine. Theoretical calculations show that replacement of 1 kg soybean meal by HPSFM-46 needs an additional 15 g synthetic lysine hydrochloride and 0.5 g synthetic threonine in the mixture for pigs and poultry (Todorov, 2011; unpublished results). The trial of Mushtaq et al. (2009) with broilers receiving compound feed with 30% SFM plus 0.9 – 1.0% lysine and enzymes xylanase and glucanase confirmed the possibility to achieve higher gain on a daily basis.

The negative effect of the high lignin content of SFM on digestibility can be compensated for by fat supplementation. For each kilogram of HPSFM-46 included in compound feed for pigs, it is necessary to add 41 g fat to become approximately equal in energy to the compound considered as a "gold standard" – soybean meal. Another possibility is pelleting the mixture to increase feed intake. However, the digestibility of amino acids (except methionine) in SFM is app. 9% lower compared to soybean meal (Stein, 2016).

Combining the new technology for processing of SFM with achievements of science for utilization of nutrients, balancing the rations and improving the energy intake by supplementation of enzymes, fats and pelleting will allow a higher effective inclusion rate of sunflower products in poultry and pig diets, which will decrease its cost.

The relatively new technology for separation of SFM in two fractions is applied in large scale in the "Bonmix" feed mill, in the town of Lovech. High protein SFM is sold in many countries. The patent is owned by Bunge Global Innovation (USA) and by GAP "Resource" (Russia).

Therefore, a large decrease of CF could be achieved by separating the hulls of sunflower seeds twice – once before pressing the seeds to extract oil, and a second time by processing SFM. The acceptable dehulling before pressing, without losing too much oil, can reduce CF to 14%, and increase the CP to 38 – 40%. This technology is applied in the mill in Stara Zagora (BG), in some mills in the USA and to a lesser extent in some other countries.

During separation of SFM into two fractions fine dust is raised. This problem can be solved by adding molasses for binding the dust or by pelleting SFM products.

Improving protein utilization of sunflower meal by ruminants

The high degree of rumen degradability (Molina Alcaide et al., 2003; Nedelkov et al., 2019) can be decreased by toasting sunflower in processing mill or additionally by steam heating or by extrusion. There have been many attempts at decreasing degradability by applying different chemicals plus heating (Arroyo et al., 2005; Mohammadabadi et al., 2009; Danesh Mesgaran and Mohammadabadi, 2010; Diaz-Royon et al., 2016), without developing acceptable technology.

The rumen undegradable protein is below 40% in traditional SFM vs. 49% for soybean meal (NRC, 2001). By appropriate toasting, it could be expected that the rumen protein degradability will be reduced from 70 – 85% to 50 – 60% and the protein digestible in intestine (PDI) will be increased from 100 – 140 to 170 – 200 g/kg SFM. It is difficult to obtain the same low level of intestinal digestibility as soybean meal, because the indigestible portion of protein in the acid detergent insoluble crude protein (ADICP) is 6.4% for SFM vs. 1.0% for soybean meal (NRC, 2001). It is expected that the toasted SFM might be a maximum of 15 – 20% more expensive than traditional SFM, while the increase of PDI is expected to be 30 – 40% higher.

Another effective technology for significant decrease of the rumen degradability is gamma irradiation of SFM (Ghanbari et al., 2015). It doesn't pollute the environment (Al-Masri, 1999; Mani and Chandra, 2003), disinfect feeds (Shawarang, 2006) increase the digestibility (Mani and Chandra, 2003; Song et al., 2009; Gambari et al., 2015) and can be applied in the future. Gamma radiation has been used successfully to decrease degradability of several other feeds (Shawarang, 2006; Shawarang et al., 2007 and 2008; Ebrahimi et al., 2009; Taghinejad-Roudbaneh et al., 2010; Ghanbari et al., 2012). The cost of irradiation is low, but initial investment is significant.

The application of additional separation of hulls in SFM for ruminants is doubtful. In spite of the fact that sunflower hulls are not good roughage, they help in the maintenance of rumen contractions and rumination.

Supplementation by ruminally protected lysine will increase the biological value of SFM. Toasting of SFM plus protected lysine could replace a bigger portion of soybean meal in diets of high producing dairy cows, goats and ewes.

The new sunflower products

Some products obtained by application of suggested additional processing of SFM are given in table 2. The animals' categories for which they are suitable as a feed are given in table 3.

Apparently, LPSFM-17 doesn't meet the animals' requirements. It is necessary to estimate experimentally the effectiveness of feeding different categories of animals with the other new sunflower products (LPSFM -25, HPSFM -46 and -50). It is necessary to prove in scientific experiments how much LPSFM-25 could be included in the diet of pregnant sows or to find the appropriate combination with other cellulose-rich feeds.

Economic problems connected with new sunflower products

The additional processing of SFM of course increases its cost. If the price of SFM with 35% CP is 0.345 €/kg, the expected prices after additional processing are shown in table 4.

As can be seen in table 4, the theoretical price of SFM products containing different levels of CP varies in a wide range. HPSFM-50 with 50% CP is app. 5 times more expensive than LPSFM-17 with 17% CP. However, the price of high protein SFM is lower compared to soybean meal.

Depending on the accepted price of a basic SFM with 35% CP, a theoretical price of sunflower products with different CP content is changed. If SFM with 35% CP becomes 0.375 €/kg, the price of HPSFM-50 (with 50% CP) will increase to 0.513, instead of 0.483 €/kg. The prices of different sunflower products might also be changed, depending on the

Table 2. Some parameters of different new sunflower products.

Feeds	CF, %	AD, %	CP, %	PD[1], %	PDI [1], g/kg	Lys. [1], g/kg	PBR[1], g/kg	FUM[1]	ME[1], pigs	ME[1], poultry
HPSFM-50	6-8	5-6	50	83	139	16.7	181	1.0-1.15	13-14	11.1
HPSFM-46	7-8	5-7	46	82	128	15.3	167	1.0-1.1	12-13	11.0
LPSFM-25[2]	26-28	8-12	25	72	65	10.5	82	0.7-0.9	–	–
LPSFM-17	36-55	14-15	16-20	42	49	6-8	38	0.54-0.6	5.0-5.5	–
Toasted SFM	15-18	6-8	32-36	60	145	15.2	86	0.85-0.9	–	–
Traditional SFM	15-29	7-12	25-36	72	65-102	12.5	82-129	0.7-0.95	9-11	7-9

Abbreviations: CF – crude fiber, ADL – acid detergent lignin, CP – crude protein, PD – protein degradation in the rumen, PDI – protein digestible in (small) intestine, Lys – lysine, PBR – protein balance in the rumen, FUM – feed units for milk, ME – metabolizable energy MJ/kg

[1] Most of data for the new products are from Nedelkov et al. (2021), and the results for pigs and poultry are presented as a theoretical calculation.

[2] Compound feed for ruminants with supplementation of molasses, minerals and vitamins.

Table 3. The categories of animals which may be feed different sunflower products.

Sunflower feeds	*Suitable for expected species and category of animals*
Low cellulose (HPSFM-46/50)	Broilers, lactation, growing and fattened pigs, salmon, dogs
Concentrate feed (LPSFM-25+)	Low producing and replacement ruminants, dry cows, goats, ewes
High cellulose (LPSFM-25)	Rabbits, finishing period of fattened pigs, pregnant sows
Toasted SFM for ruminants	Dairy cows, goats and ewes, young and growing ruminants
Traditional sunflower meal	All species and categories, with limitations

Table 4. Theoretical prices in Euro for 1000 kg of sunflower meal products.

Crude protein content, %	17	25	30	35	40	46	50
Price depending on energy and protein value of feeds	95	210	300	345	370	400	420
Expected cost of additional processing	9[1]	24[2]	0	0	20[3]	60[4]	63[4]
Theoretical price of sunflower products	101	234	300	345	390	460	483
Prices of diet supplements	–	–	–	–	–	60[5]	60[5]
Theoretical prices for farmer	104	234	300	345	390	520	543

[1]Addition of molasses,

[2]Addition of molasses, minerals and vitamins to become compound feed for ruminant animals,

[3]Losses of oil due to excess removal of hulls before pressing,

[4]Cost of mechanical separation into two fractions (15%),

[5]Expenses for addition of fat and enzymes for increasing energy value, and addition of amino acids for equalizing biological value with soybean meal.

price of additionally-included supplements to diets which compensate for their nutritional deficits. Replacing soybean meal in poultry diets allows a decrease in supplements of synthetic methionine and to decrease the cost of diets. This effect is not included in table 4.Therefore, replacement of soybean by low cellulose SFM plus necessary supplements will be more profitable compared to calculations made in table 4.

The theoretical prices in table 4 can be used for a rough comparison with the price of soybean meal. A more exact calculation of economic benefits after inclusion of the new sunflower products in rations for different categories of animals could be made by diet formulation using SFM product and soybean meal. Accuracy can be improved by including real animal productive data, slaughter results and the quality of animal products.

Scientific problems awaiting answers

The experiments with new sunflower products carried out so far has received only limited attention (Nedelkov et al., 2021). They gave some information for chemical composition, digestibility of nutrients, and rumen degradability only for HPSFM-46. There are data about digestibility in the small intestine of protein avoiding degradation in rumen. On this basis, protein digestible in the small intestine (PDI) and protein balance in the rumen (PBR) for HPSFM-46 were calculated. In some single productive trials conducted with chicken and pigs, soybean meal was successfully replaced by HPSFM-46. When the amount of HPSFM-46 was increased to 10% in the mixture for broilers and up to 20% in finisher for pigs, there was a tendency for a decrease in the daily gain ($P = 0.056$, Nedelkov, unpublished results). There is a lack of experiments with other species and others of the new sunflower products.

To clarify arising questions before the wider application of the new sunflower products in animal feeding, it is necessary to have collaboration between technologists and nutritionists. It is needed to optimize the toasting process of SFM for ruminants in order to achieve a decrease of the rumen degradability, without damaging intestinal digestibility of the protein. The estimation of the best means for avoiding fine powder in new sunflower products arising during processing of SFM also requires studies. It is possible to apply molasses, pelleting of sunflower products, or other methods. To optimize the level of CP and CF in the high cellulose fraction of SFM also requires further studies. Research organizations have to carry out experiments to determine energy and protein value of the new sunflower products, as well as to optimize the level of their inclusion in the ration of different species and categories of animals. Special experiments are needed to demonstrate the impact of high cellulose products on performance and welfare of animals.

It is necessary to establish the most suitable categories of animal for the new products and for traditional SFM.

The degree of substitution of soybean meal by different new sunflower products and by toasted SFM for ruminants and its impact on production, quality of animal products and the economics of the farm is another noteworthy field for animal trials.

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