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Original research paper

PROTEIN ENRICHMENT OF SUNFLOWER MEAL BY AIR CLASSIFICATION

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ABSTRACT: Sunflower meal is a by-product that remains after oil extraction from sunflower seeds. It is produced in large quantities and it is mostly used as protein source in animal feed production. Thus, protein content is an important quality parameter of sunflower meal. Removal of sunflower hull decreases the crude fiber content, increases the crude protein content and nutritional value of sunflower meal. The aim of this study was to evaluate the process of air classification for obtaining protein enriched fractions of sunflower meal. The conical mill was used to reduce the size of particles and agglomerates of sunflower meal. Air flow and feeding rate were varied during air classification process. At each air flow setting protein enriched fractions that had significantly higher ($p<0.05$) crude protein content than the unclassified sunflower meal were obtained. Increase of air flow resulted in coarse fractions with higher protein content and lower yield.

Key words: *sunflower meal, air classification, protein enrichment, conical mill*

INTRODUCTION

Sunflower is one of the world's major oilseeds. After solvent extraction of oil from sunflower seeds remains sunflower meal (SFM) as a valuable by-product. Due to large quantities of SFM there is common interest in its proper utilization. SFM is primarly used in animal feed production as protein and energy source. It can be also used as fertilizer, substrate for growth of microorganisms or combustible source of energy (Lomascolo et al., 2012).

Chemical composition of SFM depends on various factors, such as sunflower variety, climate, soil and extraction process (Lomascolo et al., 2012). Protein content, the most important nutritional component of this feedstuff, ranges from 29 to 48% (Boni et al., 1987; Ramachandran et al., 2007; Geneau-Sbartaï et al., 2008). Crude fiber is a second important component of SFM, and its content usually ranges from 18 to 23%. Crude fiber content is a limiting factor for the usage of SFM in diet formulation for monogastric animals considering the animal's nutrient requirements (Čolović et al, 2010, Szabo et al., 2013). Sunflower hull, rich in crude fiber, has adverse effect on animal's welfare and performance. Protein and fiber content of SFM are inversely related. Thus, for the increase of nutritive and economical value of this valuable ingredient sunflower hull must be removed, which decreases crude fiber content and increases protein content.

Comparing with extraction meals of other oilseeds, sunflower meal is high in raw fiber and phenol content but it has relatively lower protein content (Boni et al., 1987). Several technological fractionation procedures, based on the differences in structural and physical properties of sunflower kernels and hulls, such as sieving, centrifugal and electrostatic separation have been used to increase the nutritive value of SFM (Sredanović, 2007).

Air classification is a technological method of separation of granular or powder materials according to particle size, density and shape into fine and coarse fractions. It is commonly used for removal of undesired components or for the enrichment of the certain components of starting material. Two factors affect air classification process – cut point of the separation and the degree of dispersion of the material that can be reached in classifier (Dijkink et al., 2007). Cut point which is the particle size at which particles have equal chance to end up in coarse and fine fraction. Large particles always end up in coarse fraction and as particle size decreases the chance for particle to end up in fine fraction increases. The quality of particle separation is characterized by mass content of each fraction in suitable product, while the product yield is mass of suitable product relative to mass of starting material (Shapiro and Galperin, 2005). Air classification in combination with sieving was applied for soybean and cottonseed meal fractionation to obtain fiber and protein rich fractions (Challa et al., 2010). Wu and Abbott (2003) were used air classification to obtain fine fractions of defatted salicornia meal enriched by protein.

In the current study, SFM was milled using conical mill. Milled SFM was air classified, by changing air flow and feeding rate, to obtain protein rich fractions.

MATERIAL AND METHODS

Sunflower meal used in this experiment was obtained from oil factory “Victoria Oil”, Šid. Conical mill (Miag, Braunschweig, Germany) was used to reduce the size of particles and agglomerates of SFM. Adjustable gap between rotary cone and stationary serrated surface was set up to its maximum to enable acceptance of large agglomerates (consisting of broken sunflower kernels and hulls) between grinding elements.

Milled SFM was fractionated by an air classification, using 1-40MZM laboratory “Zig-Zag” air classifier (Hosokawa Alpine, Augsburg, Germany). Parameters which were varied during air classification of SFM were rotation speed of dosing element and the air flow. Rotation speed of dosing element was set at 30, 60 and 90%, respectively, and air flow was set at 5, 8.7 and 12.5 m^3/h, respectively.

Feed rate was determined by measuring the time needed for the classification at each combination of air flow and rotation speed of dosing element. It was calculated as:

$$Q = \frac{C + F}{T}$$

where Q represents feed rate, C and F are masses of obtained coarse and fine fractions respectively, and T represents classification time. Yields of obtained fractions was calculated according to equations:

$$\gamma_C = \frac{C}{C + F} \qquad \gamma_F = \frac{F}{C + F}$$

where γ_C and γ_F represents yield of coarse and fine fractions respectively, C mass of coarse fraction, and F mass of fine fraction.

Bulk density was measured with a bulk density tester (Tonindustrie, West und Goslar, Germany). Particle size distribution of SFM prepared by conical mill was determined by standard sieving analysis (ISO Standard 2591–1:1988 (E)) using laboratory sieves ranging from 63 to 2500 μm (Endecotts Ltd., United Kingdom).

Unclassified SFM and classified SFM fractions were analyzed to moisture content (AOAC Method 934.01), crude protein content (AOAC 978.04 Method), and crude fiber content (AOAC 978.10 Method). Additionally, unclassified SFM was analyzed to crude ash (AOAC Method 942.05) and crude fat content (AOAC 920.39 Method).

One–way ANOVA and Tukey honestly significant difference test were used to analyze variations of the results. Differences between the means with probability $p < 0.05$ were accepted as statistically significant and differences between the means with $0.05 < p < 0.10$ were accepted as tendencies towards differences. The level of confidence was set at 95% (STATISTICA 10.0, StatSoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSION

Results of chemical composition of starting SFM are presented in Table 1.

Figure 1 shows particle size distribution of SFM milled by conical mill. 25.8% of particles were in size range from 1.25 to 2 mm as nearly 50% of particles were larger than 1.25 mm. Bulk density of milled SFM was 0.430 kg/dm^3.

The feed rate of classification at each air flow setting and rotation speed of dosing element, together with the yield of obtained fractions are presented in Table 2. As expected, higher percent of dosing speed had lead to higher feed rate and shorter time needed for fractionation of the same amount of the material. SFM fractions, obtained at all combinations of air flow and rotation speed of dosing element, had crude protein content significantly different ($p<0.05$) from the unclassified SFM. Results of protein content of SFM fractions obtained at 30% of dosing speed are shown in Figure 2. Fine fraction of SFM obtained at flow rate of 5 m^3/h had higher protein content than that of starting SFM, probably because air flow of 5 m^3/h was too low to fiber rich hulls end up in fines. Therefore, large hulls were pulled down in coarse fraction by gravity. Only finely ground particles ended up in fine fraction, but the yield of fraction was only 7.73%, with the protein enrichment of 2.82% compared with the starting material.

Coarse fraction obtained at 12.5 m^3/h had higher value of crude protein content than that obtained at 8.7 m^3/h. Air flow of 12.5 m^3/h was sufficient enough to drag up significant amount of sunflower hulls into fines and to get coarse fraction richer in protein for 12% compared to the starting SFM, while the protein enrichment of coarse fraction at 8.7 m^3/h was only 1.76%.

Similar results of protein enrich-ment were achieved by Wu and Abbott (2003). These authors successfully used air classification process for 2.9 – 11% protein content enrichment of pin milled defatted salicornia meal, compared to the starting material.

Figure 3 shows that all fractions obtained at 60% of rotation speed of dosing element follow the same trend in crude protein content as the ones obtained at dosing speed set at 30%. Fine fractions obtained at 5 m^3/h and coarse fractions obtained at 8.7 and 12.5 m^3/h had significantly higher protein content than the starting SFM ($p<0.05$). Protein enrichment of fine fraction obtained at 5 m^3/h was 3.25%, while that of coarse fractions obtained at 8.7 and 12.5 m^3/h was 1.22% and 9.75% respectively.

The same can be noticed for fractions obtained at 90% of rotation speed of dosing element (Figure 4). The coarse fraction obtained at 12.5 m^3/h had 7.91%, while fine fraction obtained at 5 m^3/h had 5.39% more protein in comparison to the crude protein content of the starting SFM. Coarse fraction at 8.7 m^3/h had the same protein content of 36.4% on dry matter basis, as that obtained at same air flow setting and 60% of rotation speed of dosing element. Air flow of 8.7 m^3/h provided the increase in coarse fractions yield, from 77.36 to 78.12%, but with low enrichment level from only 0.98% to 1.76% in comparison to the unclassified SFM.

Table 1.
Chemical composition of unclassified sunflower meal

Chemical composition	(%)
Moisture	9.02
Crude protein	35.99*
Crude fiber	19.39*
Crude fat	2.13*
Crude ash	6.75*
Nitrogen free extracts (NFE)	35.73*

** expressed at dry matter basis*

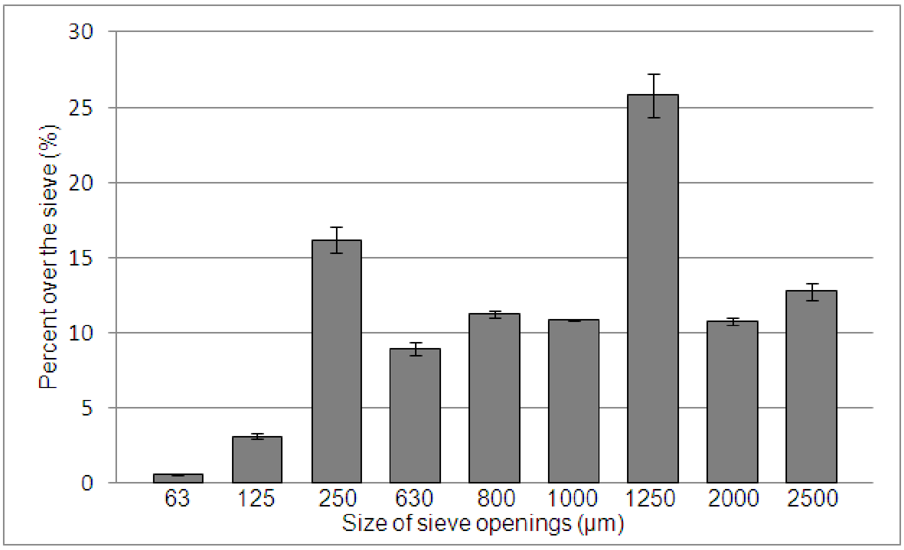

Figure 1. Particle size distribution of sunflower meal milled by conical mill

Table 2.
Feed rate and the yield of obtained fractions

Air flow (m^3/h)	Rotation speed of dosing element (%)	Feed rate (kg/h)	Yield (%)	
			Coarse fraction	Fine fraction
5.0	30	0.77	92.27	7.73
5.0	60	4.06	91.58	8.42
5.0	90	10.70	93.80	6.20
8.7	30	0.60	77.85	22.15
8.7	60	3.92	77.36	22.64
8.7	90	10.21	78.12	21.88
12.5	30	1.06	52.50	47.50
12.5	60	3.80	54.17	45.83
12.5	90	8.09	55.00	45.00

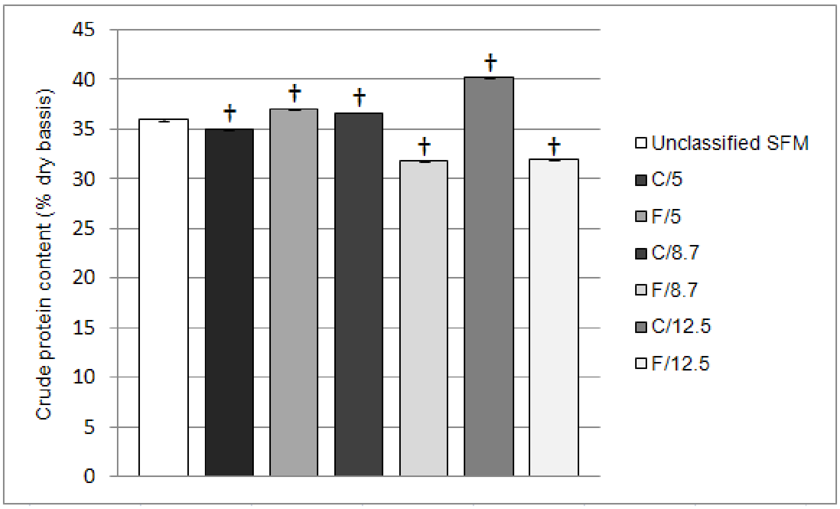

Figure 2. Crude protein content of SFM fractions obtained at rotation speed of dosing element set at 30% (SFM-sunflower meal; C-coarse fraction; F-fine fraction; 5, 8.7, 12.5-air flow in m^3/h)
Results are given as mean ± Standard Deviation
†- means are significantly different compared to the unclassified meal ($p<0.05$)

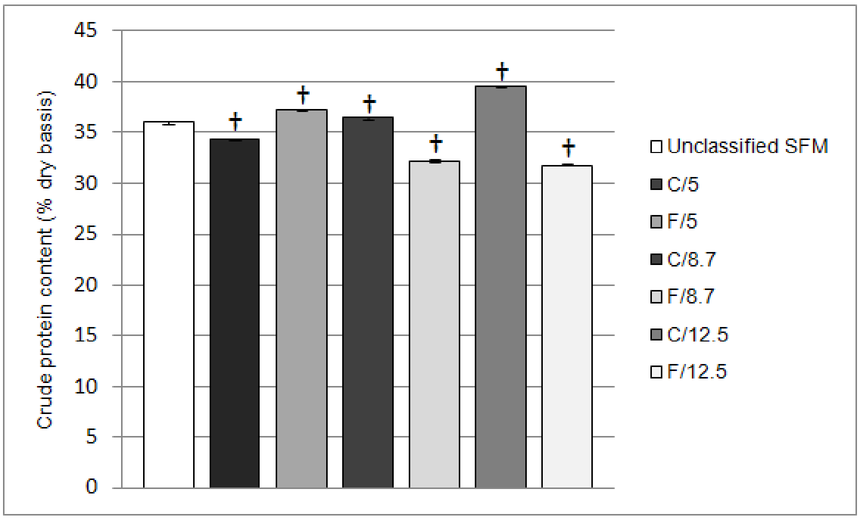

Figure 3. Crude protein content of SFM fractions obtained at rotation speed of dosing element set at 60% (SFM-sunflower meal; C-coarse fraction; F-fine fraction; 5, 8.7, 12.5-air flow in m^3/h)
Results are given as mean ± Standard Deviation
†- means are significantly different compared to the unclassified meal ($p<0.05$)

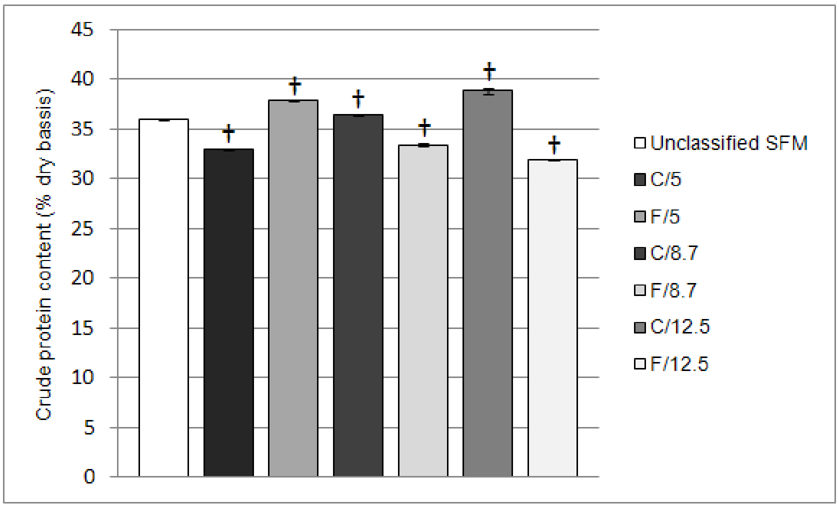

Figure 4. Crude protein content of SFM fractions obtained at rotation speed of dosing element set at 90% (SFM-sunflower meal; C-coarse fraction; F-fine fraction; 5, 8.7, 12.5-air flow in m^3/h)
Results are given as mean ± Standard Deviation
†-means are significantly different compared to the unclassified meal ($p<0.05$)

Fine fractions obtained with air flow setting of 5 m^3/h were enriched in protein from 2.86 to 5.39%, compared with the starting SFM, but the yields were low and went from 6.20 to 8.42%.The best enrichment in protein was achieved using air flow of 12.5 m^3/h at each setting of rotation speed of dosing element. Still, these fractions had lower crude protein content as fraction that Sredanović (2007) obtained by centrifugal separation which had 44% crude protein. By studying the protein enriched SFM fractions obtained at 12.5 m^3/h and comparing them, it could be noticed that as the applied rotation speed of dosing element increases, the protein content in these fractions significantly decreases ($p<0.05$). At the higher dosing rate of the SFM, more material goes to the classifying chamber, so the air stream can not drag grinded hulls into fines and more hulls cross it towards the opposite walls of zigzag channel and end up as coarse particles. The yields of coarse fractions obtained at this air flow also show that because yield increased from 52.50% to 55% with increase of applied dosing speed.

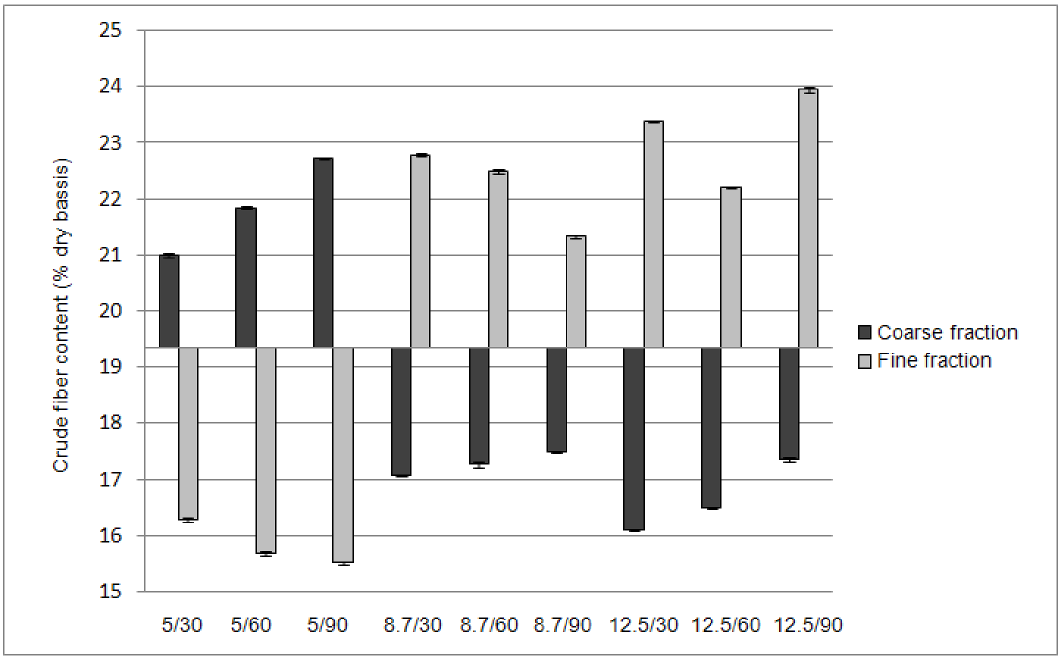

Figure 5. Changes in crude fiber content of SFM fractions (5, 8.7, 12.5- air flow in m^3/h; 30, 60, 90- rotation speed of dosing element in %)

This is probably also the reason that protein content of fine fraction obtained at 5 m^3/h and 90% of dosing speed was significantly higher than that of fine fraction obtained at same air flow and 30% of rotation speed of dosing element.

The increase in protein content was followed by the decrease in fiber within the same fraction. The changes in crude fiber content of fractions, presented in Figure 5, were significantly different ($p<0.05$) for all fractions compared to the unclassified SFM.

CONCLUSIONS

Air classification of sunflower meal milled by conical mill was effective for obtaining protein enriched fractions. All protein enriched fractions had significantly higher protein content than that of starting material. Protein content and yield of obtained sunflower meal fractions was affected by air flow setting. The increase in air flow resulted in coarse fractions with higher protein content but with lower yield. Thus, protein enrichment and yield combination can be adjusted by modulating the air flow. Low dosing speed of the material into classifier led to low feed rate and therefore more time was needed for classification of same amount of sunflower meal.

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ПОВЕЋАЊЕ САДРЖАЈА ПРОТЕИНА СУНЦОКРЕТОВЕ САЧМЕ ПОСТУПКОМ ВАЗДУШНЕ КЛАСИФИКАЦИЈЕ

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Сажетак: Сунцокретова сачма представља споредни производ који заостаје у великим количинама након екстракције уља из сунцокрета. Највише се користи у производњи хране за животиње као извор протеина. Садржај протеина је стога битан параметар квалитета сунцокретове сачме. Уклањањем љуске сунцокрета, смањује се садржај сирових влакана, повећава се садржај протеина, а тиме и нутритивна вредност сунцокретове сачме. Циљ рада био је да се процени поступак ваздушне класификације у сврху добијања високопротеинских фракција сунцокретове сачме млевене на конусном млину. Конусни млин је коришћен за уситњавање честица и грудви сунцокретове сачме. Током ваздушне класификације, варирани су проток ваздуха и брзина дозирања. При сваком коришћеном протоку ваздуха добијене су фракције са значајно вишим ($p<0.05$) садржајем сирових протеина од почетне сунцокретове сачме. Повећање протока ваздуха резултовало је мањим приносом тежих фракција, које су имале виши садржај протеина.

Кључне речи: *сунцокретова сачма, ваздушна класификација, обогаћење протеинског садржаја, конусни млин*

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