Removal of Cellulose from Sunflower Meal by Fractionation

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The dependence of sunflower meal fractionation on the following factors was investigated: quality of original meals, 37.5%, 40.0% and 42.5% crude protein; screen hole size, 1.5 mm, 2.0 mm, 2.5 mm and 3.0 mm; and single-phase and two-phase fractionation. The following conclusions were drawn. The increased protein levels in original meals (from 37.5% to 42.5% crude protein) had considerably greater effects on the quality than on the yield of the protein fractions. Increased screen hole size (from 1.5 mm to 2.5 mm) increased the yield of the protein fractions by 16.4–22.3%, but reduced the protein level in these fractions by 2.3–2.8%. Two-phase fractionation of the original meals with 40.0% and 42.5% crude protein increased the protein yield in the resulting protein fractions by 15.5–22.8%. The most efficient fractionation procedures rendered high yields of attractive protein fractions that contained 44.0–47.5% crude protein. The protein fractions were analyzed for physico-functional constants and amino acid composition. The most efficient and applicable fractionation procedures, those that may be successfully used in oil refineries, were selected.

KEY WORDS: Amino acids, decellulosing, fractionation, physical characteristics, protein fraction, sunflower meal.

Conventional sunflower meals contain 34% and 37% crude protein and 23% and 18% crude cellulose (1). These unpopular meals are mixtures of protein-containing kernels and hulls in the approximate ratios of 60:40% to 65:35%. It is known that high hull levels cause drastic reductions in the digestibility and biological value of the meal fed to poultry and monogastric animals (2–8). Separation of the hull from the kernel is the key to improving the nutritional and commercial values of sunflower protein.

Several procedures and complex systems for separating hulls from kernels and meal have been investigated. The following seem to be attractive for oil refineries: i) efficient industrial procedures exist for dehulling, which allow the hull level in the material for pressing to be reduced to 6–10%. Such materials for pressing can be used for the production of meals containing 40–44% crude protein (9–22). ii) Combined procedures of adequate dehulling plus fractionation of the original meal containing reduced hull levels render decellulosed meals with 47–50% crude protein (23–29).

The fractionation of original sunflower meal is based on the diametrically opposed physical, chemical and electrodynamic characteristics of the kernel and the hull (24,25,30). The fractionation procedures allow the original meal to be separated into two or more fractions, which differ in quality—fine protein fraction, which passes through the screen, and a crude cellulose fraction, which flows over the screen. The protein fraction is used for feeding poultry and monogastric animals, the cellulose fraction for feeding ruminants.

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The intent of this work is to advance the industrial procedures of fractionation of the original sunflower meals that are presently used in Yugoslavia.

MATERIALS AND METHODS

The original meals were produced from domestic oil-type seeds that contained about 74% kernel and 26% hull. Materials for pressing with *ca.* 15.0%, 12.5% and 10.5% hull were obtained by regulating the huller. After oil extraction from these materials (pressing in an expeller press, flaking, extraction with *n*-hexane), original meals were produced that contained 37.5%, 40.0% and 42.5% crude protein. After drying, the granulometric composition of the original meals was approximately 22% particles larger than 5.0 mm, 37% particles between 2 mm and 5 mm, and 41% particles smaller than 2 mm.

The fractionation of the meals was carried out in a semi-industrial separator, consisting of a fixed centrifugal screen and a rotor for conveying and loosening the meal. The separator had the following capability: Speed, 1,455 rpm; screen area, 0.6 m^2; screen hole sizes, 1.5 mm, 2.0 mm, 2.5 mm and 3.0 mm; screening areas, 0.19 m^2, 0.23 m^2 and 0.28 m^2 for the 1.5 mm, 2.0 mm and 2.5 mm screens, respectively; and mass flow per unit of time, 300 kg/h, 400 kg/h and 500 kg/h for the 1.5-mm, 2.0-mm and 2.5-mm screens, respectively. Two-phase fractionation was applied to the original meals that contained 40.0% and 42.5% crude protein.

Five samples of meal were taken from each experimental treatment for chemical and physical analyses. The macro-chemical composition of the meals was determined by the AOAC methods (31), the bulk mass according to DIN (32), the specific gravity according to DIN (33) and the water and oil absorption capacity by the AFMA methods (34). Amino acids were determined with a Biotronic-Model LC 5001 analyzer (Biotronik, Frankfurt, Germany). The samples were hydrolyzed prior to analysis (35), and cystine and methionine were oxidized with performic acid. Tryptophane was determined spectrophotometrically.

RESULTS AND DISCUSSION

Fractionation of the original meals. For the single-phase fractionation of the original meal that contained 37.5% crude protein, the best results were obtained with the 1.5-mm and 2.5-mm screens. Production of the protein fraction with the former screen was 43.4% and the fraction contained 43.8% crude protein. With the latter screen, production of the protein fraction was 65.6% and the fraction contained 41.0% crude protein. Both screens rendered cellulose fractions that were reasonably good for feeding ruminants. Their crude protein contents were 32.5% and 30.8%, respectively (Table 1).

In single-phase fractionation of the original meal that contained 40% crude protein, the best results were obtained with the 2.5-mm screen. The protein fraction yield was 65% and the fraction contained 43.6% crude protein. Two-phase fractionation is technologically advantageous on 1.5-mm + 2.0-mm screens and 2.0-mm + 2.5-mm

TABLE 1

Results of Single-Phase Fractionation of Original Meal Containing 37.5% Crude Protein (8.0% moisture)

Parameters (%)	Original meal	Passing material—protein fraction		
		1.5 mm	2.0 mm	2.5 mm
Protein fraction yield	100.0	43.4	50.2	65.6
Flowing material yield	100.0	56.6	49.8	34.4
Chemical composition of protein fraction				
Crude protein	37.5	43.8	42.1	41.0
Crude fiber	19.2	12.3	15.2	16.0
Crude fat	1.8	1.6	1.7	1.7
Ash	6.8	7.2	7.0	7.0
Crude protein in cellulose fraction of flowing material	—	32.5	32.6	30.8

screens. The first procedure increased the yield of the protein fraction by 21.6%, the second by 20.8% (Table 2).

With single-phase fractionation of the original meal that contained 42.5% crude protein, the best results were obtained with the 1.5-mm and 2.0-mm screens. Both procedures rendered 50–54% of the protein fraction with 47% crude protein. Both screens produced quality cellulose fractions for repeated fractionation, with 38.2% and 37.6% crude protein, respectively. The two-phase fractionation was technologically advantageous on the 1.5-mm + 2.0-mm screens and 2.09-mm + 2.5-mm screens. The first procedure increased the yield of the protein fraction by 20.7%, the second by 20.2% (Table 3).

Fractionation factors and distribution of crude protein. The following correlations are relevant from both theoretical and practical aspects; screen hole increase from 1.5 mm to 2.5 mm increased the distribution of crude protein in the protein fractions by 14.8–21.1%, while it reduced the levels of crude protein in these fractions by only 2.3–2.8%. Two-phase fractionation of the original meals with high protein levels (40.0% and 42.5%) increased the distribution of crude protein in the protein fraction by 20.5–22.8% respectively, and by 15.5–21.6%, respectively. The increased protein levels in the original meals with 37.5% and 42.5% crude protein had a much higher effect on the quality than on the yield of the protein fraction (Tables 1–4). Further clarification of the above correlations will probably increase the yield and improve the quality of protein fractions.

TABLE 2

Single-Phase Fractionation of Original Meal Containing 40.0% Crude Protein (8.4% moisture)

Parameters (%)	Original meal	Passing material—protein fraction		
		1.5 mm	2.0 mm	2.5 mm
Protein fraction yield	100.0	46.4	51.0	65.0
Flowing material yield	100.0	54.0[a]	49.0[b]	35.0[c]
Chemical composition of protein fraction				
Crude protein	40.2	44.8	44.0	43.6
Crude fiber	15.8	11.2	11.5	12.0
Crude fat	1.8	1.5	1.6	1.6
Ash	6.9	7.2	7.0	7.0
Crude protein in cellulose fraction of flowing material	—	37.0	36.8	34.1

[a] Repeated screening of this fraction with the 2.0-mm screen rendered 21.6% of protein fraction with 42.5% crude protein.

[b] Repeated screening of this fraction with the 2.5-mm screen rendered 20.8% of protein fraction with 42.0% crude protein.

[c] This fraction is not suitable for two-phase screening.

TABLE 3

Single-Phase Fractionation of Original Meal Containing 42.5% Crude Protein

Parameters (%)	Original meal	Passing material—protein fraction		
		1.5 mm	2.0 mm	2.5 mm
Protein fraction yield	100.0	50.0	54.0	66.4
Flowing material yield	100.0	50.0[a]	46.0[b]	33.6[c]
Chemical composition of protein fraction				
Crude protein	42.6	47.3	47.0	45.0
Crude fiber	15.2	9.8	10.3	11.4
Crude fat	1.7	1.5	1.5	1.6
Ash	7.0	7.5	7.5	7.3
Crude protein in cellulose fraction of flowing material	—	38.2	37.6	37.6

[a] Repeated screening of this fraction with the 2.0-mm screen rendered 20.7% of protein fraction with 44.0% crude protein.

[b] Repeated screening of this fraction with the 2.5-mm screen rendered 20.2% of protein fraction with 43.0% crude protein.

[c] Repeated screening of this fraction with the 3.0-mm screen rendered 15.8% of protein fraction with 42.0% crude protein.

Physicochemical characteristics and amino acid composition of the protein fractions. The protein fractions with 44% and 47% crude protein possessed an exceptionally fine granulation (44.8% and 75.4% particles smaller than 500 microns, respectively), intermediate bulk mass (500 and 570 kg/m^3, respectively) and an outstandingly high capacity for absorbing fats A(2.2 and 2.4 cm^3/g, respectively) (Table 5).

Compared to soybean meal with 48% crude protein, the sunflower protein fraction with 47% crude protein contains an approximately equal concentration of essential amino acids (25.50% and 24.73%, respectively), a considerably lower concentration of lysine (2.89% and 1.71%, respectively) and a considerably higher concentration of methionine (0.63% and 1.26%, respectively) (Table 6). Therefore, the two protein components are highly complementary biologically. The protein fraction with 47% crude protein is a potential basis for the production of attractive protein fractions with 50% or more crude protein, applicable for human food. It is known that such sunflower protein fractions do not contain antinutritional substances, but do have a pleasing taste, good functional characteristics and an attractive amino acid profile (36–40).

TABLE 4

Protein Yield in Fine Fraction Depending on Screen Hole Size and Fractionation Phase

Fractionation parameters	Crude protein yield in fine fraction (%)		
	From original meal with 37.5% CP[a]	From original meal with 40.0% CP	From original meal with 42.5% CP
Single-phase fractionation			
1.5 mm	50.6	51.3	55.4
2.0 mm	56.2	55.7	59.6
2.5 mm	71.7	70.4	70.2
Two-phase fractionation			
1.5 mm + 2.0 mm	—	74.1	77.0
2.0 mm + 2.5 mm	—	76.2	80.0
2.5 mm + 3.0 mm	—	—	85.7

[a]CP, crude protein.

TABLE 5

Physical and Functional Characteristics of Protein Fractions

Characteristics	Meal with 44% crude protein	Meal with 47% crude protein
Specific gravity (g/cm^3)	1.27	1.34
Bulk mass (mg/cm^3)	500.0	570.0
Modulus of fineness	2.10	1.73
Modulus of uniformity	0:4:6	0:2:8
Water absorption capacity (cm^3/g)	2.40	2.80
Fat absorption capacity (cm^3/g)	2.20	2.40
Granulation (%)		
1.0–2.0 mm	12.6	6.0
0.5–1.0 mm	42.6	18.6
Smaller than 0.5 mm	44.8	75.4

TABLE 6

Amino-Acid Composition of Sunflower Meal with 47.0% Crude Protein

Essential amino acids (%)	Sunflower meal with 47.3% crude protein[a]	Soybean meal with 48% crude protein[b]
Lysine	1.71	2.89
Methionine	1.26	0.81
Cystine	0.81	0.67
Threonine	1.78	1.82
Tryptophane	0.63	0.62
Arginine	4.29	3.45
Glycine	2.54	1.93
Histidine	1.10	1.23
Isoleucine	2.24	2.28
Leucine	2.85	3.55
Phenylalanine	2.19	2.36
Tyrosine	1.10	1.71
Valine	2.23	2.36
Total essential amino acids	24.73	25.50

[a]Our findings. [b]Reference 1.

Practical application of the results. Based on the experimental data on the technical efficiency of fractionation, the biological value of the protein fractions and an estimate of the required investment for the necessary machinery, the following procedures, which are most adequate for oil refineries, can be recommended. i) Single-phase fractionation of the original meal with 37.5% crude protein on a 1.5-mm screen. This procedure allows the production of 43.3% protein fraction with 43.8% crude protein from the original meal. It is applicable in oil refineries that do not use an efficient method of dehulling (Table 1). ii) Single-phase fractionation of the original meal with 40% crude protein on a 2.5-mm screen. This procedure allows the production of 65.0% protein fraction with 43.6% crude protein from the original meal and is recommended for oil refineries that use an improved method of dehulling (Table 2). iii) Two-phase fractionation of the original meal with 42.5% crude protein with 1.5-mm + 2.0-mm screens or 2.0-mm + 2.5-mm screens. These procedures allow the production of 70.7–74.2% protein fractions containing 47% and 44% crude protein. They are applicable in oil refineries that already employ efficient methods of sunflower seed sorting and dehulling.

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