Chemical, Functional, and Nutritional Properties of Sunflower Protein Products

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ABSTRACT

Sunflower flours and protein concentrates have potential food uses because of their high protein content, white color, bland flavor,and absence of antinutritive factors. Procedures have been developed for removal of chlorogenic acid which forms green and brown colors under alkaline pH, and selection for low chlorogenic acid cultivars is underway in plant breeding programs. Further research is needed on dehulling techniques and possible problems associated with high levels of sugars in sunflower flour. Sunflower flours and concentrates have excellent fat absorption, oil emulsification, and whipping properties. Wieners supplemented with sunflower products showed low shrinkage during the smokehouse treatment and low cooking losses due to high fat and water absorptions. Sunflower-supplemented wieners did score poorly in peelability and organoleptic tests. Sunflower proteins had an excellent amino acid balance except for low lysine content and, in feeding trials with rats, showed high protein efficiency ratios when blended with legume or meat proteins.

INTRODUCTION

During the past fifteen years, the usage of concentrated seed proteins in human and pet foods has increased markedly because of greater knowledge of functional properties, processing techniques, and nutritive value. While soybeans have a competitive advantage over other sources of plant protein, research is underway in many laboratories to develop alternate sources of concentrated seed protein. Sunflower proteins in particular have unique functional properties which may expand the range of food uses for concentrated seed proteins. The characteristics, processing, and utilization of sunflower oil, meal, and flour have been reviewed by Robertson and Burns (1). The objectives of the present paper are to summarize the recent investigations conducted in our laboratory on sunflower protein chemistry, processing, functionality, food uses, and nutritive value.

COLOR AND FLAVOR

In the past, sunflower meals have not been refined into food-grade products because of the dark fibrous appearance of the meal. Adverse colors and flavors in sunflower protein products are associated with the presence of hulls, polyphenolic compounds, and low molecular weight carbohydrates.

Sunflower kernels are enclosed in a thick hull which constitutes 25% of the seed weight in most oilseed cultivars. Complete dehulling is difficult to achieve in commercial practice and may lower the efficiency of oil extraction. To produce a food-grade product, it may be necessary to remove the residual hulls by air separation after oil extraction of partially dehulled kernels. Confectionery cultivars contain 40-50% hulls which can be readily separated from the meats by mechanical techniques.

Sunflower seeds also contain significant quantities of phenolic compounds which remain in the flour after oil extraction. Sabir et al. (2) reported that the total composition of phenolic compounds in Commander, Majak, and Valley sunflowers varied between 3.0 and 3.5 g per 100 g of flour. Chlorogenic acid, its isomer, and caffeic acid constituted about 70% of the total phenolic compounds in the defatted flour of each cultivar (Table I). Neutral compounds related to p-coumaric, isoferulic, and sinapic acids as well as a hydroxycinnamic acid-sugar ester were also detected by chromatographic methods. The sinapic acid-like compound, which may have adverse flavor effects, represented 15% of the total phenolic compounds in these flours.

Under neutral and alkaline conditions, sunflower proteins develop dark green and brown colors because of bonding with oxidation products of polyphenolic compounds, especially chlorogenic acid (3,4). Sephadex gel chromatography was used to demonstrate that most protein fractions were free of chlorogenic acid, but low molecular weight polypeptides were bound to about one-half of the soluble chlorogenic acid in the flour (4). In the presence of a strong hydrogen bonding agent, 7 M urea, about two-thirds of the salt-soluble polypeptides were shown to be hydrogen bonded and the remainder covalently bonded to chlorogenic acid derivatives.

Sunflower meals and flours also contain high proportions of di- and oligosaccharides which may cause darkening of sunflower-supplemented food products (5,6). While monosaccharides constituted only 0.6% of the product, Sabir et al. (7) found 4.4% sucrose, 0.9% maltose, 2.0%

TABLE I

Composition of Phenolic Constituents in Defatted Sunflower Flours in g/100 g of Flour[a]

Tentative identification of phenolic compound	Sunflower cultivar Commander	Majak	Valley
Bicarbonate soluble fraction (acid)			
trans-Cinnamic acid	0.06	0.07	0.05
Caffeic acid	0.18	0.16	0.17
Chlorogenic acid	1.97	1.94	2.08
Chlorogenic acid isomer	0.17	0.13	0.12
Bicarbonate insoluble fraction (neutral)			
p-Coumaric acid like	0.09	0.11	0.10
Isoferulic acid like	0.17	0.16	0.14
Sinapic acid like	0.48	0.57	0.48
Unknown	Trace	Trace	Trace
Unknown	Trace	Trace	Trace
Hydroxycinnamic acid-sugar ester	0.15	0.18	0.20

[a]See Sabir et al. (2).

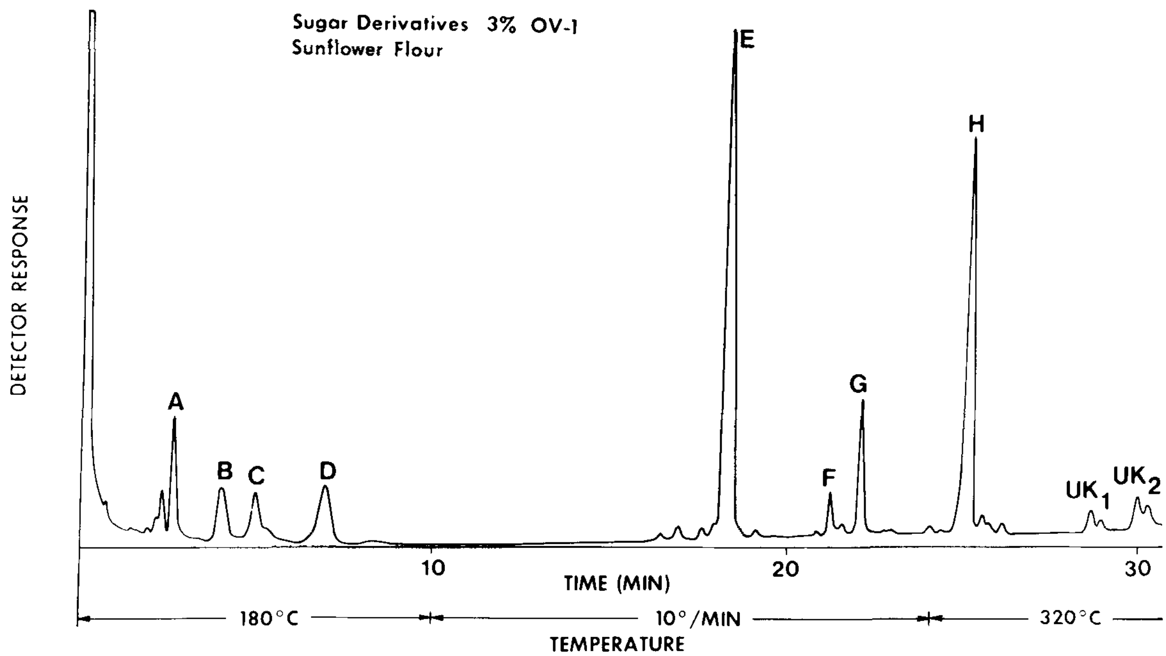

FIG. 1. Chromatogram of oxime trimethyl silyl (TMS) derivatives of reducing and TMS derivatives of nonreducing sugars in ethanol extracts from sunflower flour. The peak identities are: (A) arabinose; (B) fructose; (C) galactose; (D) inositol; (E) sucrose; (F) maltose; (G) melibiose; (H) raffinose; UK_1; UK_2 (7).

melibiose, and 2.5% raffinose in the defatted flour (Fig. 1). Although not stachyose, the two unknown sugar components with long retention times appeared to be triose or tetrose sugars. In legumes, the latter compounds are associated with flatulence, but this problem has not been reported to occur in sunflower-based diets. Protein concentrates prepared by aqueous extraction contain only low concentrations of di- and oligosaccharides.

Gheyasuddin et al. (8) prepared a colorless isolate by treating the soluble protein with sodium sulfite and washing the precipitated protein with 50% isopropanol. A process for the aqueous diffusion of chlorogenic, caffeic, and quinic acids and simple sugars from dehulled sunflower kernels has been described (9). With a six-stage countercurrent procedure, Fan et al. (10) was able to extract over 90% of the chlorogenic acid from the kernels using 70% ethanol or dilute acid at a solvent-to-seed ratio of only 3:1 w/v. After the kernels were defatted, the resulting "flour" was a protein concentrate containing over 70% protein and was light in color under alkaline pH conditions. Plant breeding to develop low chlorogenic acid cultivars is also underway, and preliminary results indicate that plant selection for this characteristic should be effective in eliminating the color problem in sunflower flour.

PROTEIN CHARACTERISTICS

The defatted flours from dehulled sunflower seeds contain nearly 60% protein, which compares favorably with other oilseed flours (11). The solubilities of sunflower proteins in the Osborne series of solvents are ca. 20, 50-60, and 3% in water, salt, and ethanolic solutions, respectively

TABLE II

Peptization of Proteins in Soybean, Rapeseed, Flax, and Sunflower Meals by the Osborne Series of Four Solvents[a]

Crop and variety	Percent of total meal nitrogen soluble in				Percent nitrogen in residue
	H_2O	5% NaCl	70% EtOH	0.2% NaOH	
Soybean, dehulled					
Portage	69.0	8.2	4.5	5.4	12.9
Altona	75.7	6.0	3.9	4.1	10.3
Rape					
Argentine	51.3	20.5	3.9	8.1	16.2
Target	50.6	20.5	4.0	9.1	15.8
Oro	48.4	22.4	3.3	8.5	17.4
Turnip rape					
Polish	44.6	24.0	4.1	6.3	21.0
Echo	44.5	25.0	4.4	6.6	19.5
Zero erucic	44.7	24.7	4.3	5.5	20.8
Flax					
Redwing	41.6	46.5	1.2	3.2	7.5
Redwood	52.1	34.4	2.0	3.5	8.0
Noralta	43.6	43.6	1.2	2.9	8.7
Sunflower, dehulled					
Commander	19.2	59.8	3.1	11.5	6.4
Advent	16.9	60.2	3.5	11.6	7.8
Peredovik	22.9	50.9	4.1	11.9	10.2

[a]See Sosulski and Bakal (11).

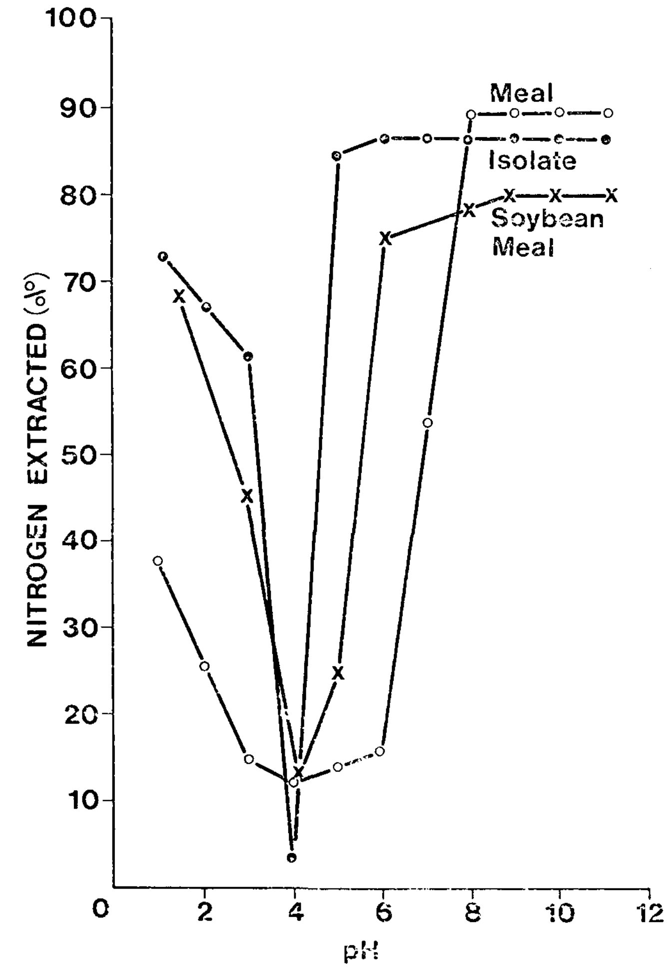

FIG. 2. Nitrogen extractability profiles for untreated sunflower meal, protein isolate, and soybean meal (14).

(Table II). Globulins constitute 70-79% of the seed proteins of which 50% had a mol wt of 330,000 and 25% had only 20,000 (12). The sedimentation coefficient for the major globulin was 12:1S.

The poor water solubility of sunflower proteins is confirmed by the extractability curve (Fig. 2) which shows sunflower meal protein as being only 15-30% soluble between pH 2 and 6 (13,14). Sunflower protein isolate was more comparable to soybean meal protein in having a narrow pH range of insolubility at pH 4-5. While sunflower proteins may appear, therefore, to have limited application in beverage products, they are highly soluble in low or high concentrations of sodium and calcium chloride, which is not the case for soybean or peanut protein (15). These salts are common constituents in many foods including ground meat and imitation milk products.

FUNCTIONAL PROPERTIES

Certain functional properties of defatted sunflower flour and protein concentrate were compared with those of soybean flour (defatted, dehulled, heat-treated) and protein concentrate (Isopro) by the procedures of Lin et al. (16). Sunflower flour was low in water absorption but exceeded soybean flour in fat absorption and oil emulsification (Table III). Sunflower concentrate showed the best water and fat absorption characteristics but was intermediate in oil emulsification. These properties suggested that sunflower products may have specific application in emulsion-type meats.

The initial foam volumes of sunflower flour and concentrate were comparable to that of Promine D, a soybean isolate with excellent foaming properties (Table IV). The foam stability of the sunflower flour during the 2-hr rest period was also similar to that of the soybean isolate but foam volumes decreased more markedly for sunflower concentrate. Soybean flour and concentrate produced foams with low initial volumes and poor stability. Sunflower flour had potential as a whipping agent if the chlorogenic acid problem could be solved by plant breeding. Aqueous extraction to remove chlorogenic acid had an adverse effect on whipping characteristics.

PROTEIN SUPPLEMENTED WIENERS

Five experimental lots of wieners were prepared using commercial meat packing plant ingredients and procedures, except that soybean and sunflower flours and concentrates were added according to the Lin et al. (17) procedure. Sufficient soy and sunflower products were incorporated into the commercial wiener mixes to increase the protein content from 12% in the control commercial samples to ca. 14% in the protein-supplemented wieners. After the smokehouse treatment, the wieners were evaluated for chemical composition, shrinkage, color, and peelability. Cooking losses, water absorption, penetrometer firmness, and organoleptic properties were evaluated after boiling the wieners for 10 min.

The added seed proteins, ca. 4% on a dry basis, served to dilute the moisture and fat levels, as illustrated by the composition of wieners supplemented with soybean flour (Table V). However, analyses of these smokehouse-heated wieners showed that those containing sunflower flour

TABLE III

Functional Properties of Soybean and Sunflower Products

Protein product	Water absorption	Fat absorption	Oil emulsification
	g/g flour	g/g flour	%
Soybean flour	2.4	0.9	16
Soybean concentrate	3.6	2.4	2
Sunflower flour	1.8	2.2	54
Sunflower concentrate	3.9	3.0	14
Standard deviation (per determination)	0.1	0.1	4

TABLE IV

Whippability and Foam Stability of Soybean and Sunflower Products

Protein product	Volume of foam after whipping, ml 1 min	30 min	60 min	120 min
Soybean flour	150^{x}[a]	108^{y}	50^{y}	10^{y}
Soybean concentrate	360^{w}	15^{z}	10^{y}	5^{y}
Soybean isolate	640^{v}	580^{v}	580^{v}	530^{v}
Sunflower flour	605^{v}	500^{w}	490^{w}	420^{w}
Sunflower concentrate	590^{v}	445^{x}	360^{x}	120^{x}

[a]Within columns, two means with no letter in common differ significantly at 95% level.

TABLE V

Effect of Oilseed Protein Supplements on the Characteristics of Wieners After the Smokehouse Treatment

	Wiener composition, dry basis			Wiener characteristics		
Protein supplement	Moisture %	Protein %	Fat %	Shrinkage[a] %	Color[b] score	Peelability[b] score
Meat control	54.9^{we}	26.0^{w}	52.0^{w}	16.3^{w}	5.0^{w}	5.8^{w}
Soybean flour	50.8^{z}	30.8^{x}	45.9^{z}	14.3^{x}	5.4^{w}	5.0^{x}
Soybean concentrate	53.8^{x}	30.8^{x}	47.3^{y}	14.9^{x}	5.2^{w}	5.8^{w}
Sunflower flour	52.4^{y}	30.4^{x}	46.8^{y}	14.9^{x}	4.0^{x}	4.8^{x}
Sunflower concentrate	55.1^{w}	30.3^{x}	48.0^{x}	14.0^{x}	4.2^{x}	4.4^{x}

[a]Percent weight loss during processing in the smokehouse and storing for 16 hr at 5 C.

[b]Subjectively scored according to a 6-point scale (6 = like most; 1 = dislike most) by a 5-member panel.

[c]Two means with no letter in common differ significantly at 95% level.

TABLE VI

Effect of Oilseed Protein Supplements on the Characteristics of Wieners after Cooking[a]

	Cooking loss		Water	Organoleptic rating		
Protein supplement	Total %	Fat %	absorption %	Flavor score[b]	Texture score[b]	Preference rating[c]
Meat control	6.3^{xy}	4.1^{wx}	1.1^{x}	4.0^{w}	4.0^{w}	0.7^{w}
Soybean flour	6.6^{wx}	4.7^{w}	2.4^{w}	3.4^{wx}	3.3^{w}	0.1^{wx}
Soybean concentrate	7.1^{w}	4.5^{w}	2.7^{w}	2.6^{x}	3.4^{w}	−0.7^{x}
Sunflower flour	5.3^{z}	3.3^{y}	2.1^{w}	2.4^{x}	3.3^{w}	−0.6^{x}
Sunflower concentrate	5.6^{yz}	3.4^{xy}	2.8^{w}	4.3^{w}	3.6^{w}	0.5^{w}

[a]Two means with no letter in common differ significantly at 95% level.

[b]Subjectively scored according to a 7-point scale (7=like most; 4=control; 1=dislike most) by a 16-member panel.

[c]Ranking difference analysis (18) by a 16-member panel.

TABLE VII

Amino Acid Composition of Seed and Animal Proteins Used in the Rat Feeding Experiments (g amino acid/16 g product nitrogen)

Amino acid	Casein[a]	Soybean[a] flour	Sunflower[a] flour	Sunflower[a] concentrate	Wheat flour	Field peas	Ground[a] beef	Standard deviation
Tryptophan	3.1	1.5	1.3	1.1	1.0	1.0	1.4	0.3
Lysine	6.4	5.4	3.1	3.2	1.9	7.1	6.9	0.8
Histidine	2.1	2.3	2.2	2.2	2.0	2.6	2.5	0.5
Ammonia	1.5	1.9	2.2	2.2	4.4	2.2	1.4	0.9
Arginine	2.8	6.9	8.2	8.2	2.9	8.6	6.4	1.8
Aspartic acid	6.0	11.4	8.6	8.5	3.7	11.6	7.9	1.5
Threonine	3.4	3.7	3.2	3.3	2.3	3.5	3.4	0.3
Serine	4.5	4.9	3.8	3.8	4.0	4.6	3.3	0.8
Glutamic acid	19.9	19.1	21.5	21.0	34.6	17.1	14.2	2.6
Proline	9.3	4.9	3.8	3.8	11.5	3.9	5.9	0.8
Glycine	1.5	4.0	5.2	5.1	2.8	4.3	8.7	0.5
Alanine	2.5	4.1	3.9	4.0	2.0	4.3	6.2	0.4
Half cystine	0.4	1.4	1.5	1.4	2.3	1.4	0.9	0.4
Valine	5.6	4.5	4.8	4.9	2.6	3.5	4.0	0.8
Methionine	3.0	1.3	2.1	2.0	1.6	1.0	2.1	0.4
Isoleucine	4.3	4.4	3.9	3.9	3.1	4.1	3.5	0.5
Leucine	8.0	7.6	6.0	6.1	6.2	7.2	6.6	0.7
Tyrosine	4.7	3.1	2.0	2.2	1.1	1.7	2.4	0.4
Phenylalanine	4.2	4.7	4.3	4.5	2.9	2.8	3.1	0.8
Protein, %	92.7	55.3	58.3	72.7	15.0	21.1	93.3	

[a]Defatted before analysis and incorporation in the diets.

retained more moisture and fat than soybean flour while those with either protein concentrate showed even higher binding properties. The protein additives reduced shrinkage during the smokehouse treatment but sunflower wieners appeared lighter in appearance and were more difficult to peel than the soybean and meat products. The lighter colors of the sunflower products can be explained on the basis of the whiteness of the proteins at the wiener pH of 5.8-5.9.

After the wieners were boiled for 10 min with casings removed, cooking losses, especially fat, were lower in sunflower-based products than in soybean-supplemented wieners (Table VI). Water absorption of all supplemented wieners exceeded the control. The flavor, texture, and preference ratings for wieners containing sunflower concentrate were comparable to that of the control. Soybean concentrate and sunflower flour wieners were rated significantly lower than sunflower concentrate in flavor and preference. The sunflower wieners, after cooking, were again noted to be lighter in color than soybean and the meat product. However, the cooking water from the wieners supplemented with sunflower flour was light green.

TABLE VIII

Effects of Protein Sources on Feed Consumption, Weight Gain, and Protein Utilization by Weanling Male Rats

	Feed consumption g/rat	Weight gain g/rat	PER[a]
Casein	276[xb]	77.0[x]	2.98[x]
Soybean flour	260[xy]	56.3[y]	2.16[y]
Sunflower flour	269[xy]	44.9[y]	1.64[z]
Sunflower concentrate	222[y]	46.5[y]	2.05[y]

[a]Protein efficiency ratio.

[b]Two means with no letter in common differ significantly at 95% level.

TABLE IX

Protein Nutritive Value of Sunflower Concentrate Blends with Lysine and Cereal, Legume and Animal Proteins

Protein source	Feed consumption g/rat	Weight gain g/rat	PER[a]
Casein	264[wxb]	72.8[x]	3.13[x]
Sunflower concentrate	229[x]	51.9[y]	2.50[y]
+ lysine	339[v]	116.7[v]	3.83[v]
+ wheat flour	241[x]	36.4[y]	1.67[z]
+ field peas	342[v]	101.7[vw]	3.31[wx]
+ ground beef	292[vw]	92.8[w]	3.52[vw]

[a]Protein efficiency ratio.

[b]Two means with no letter in common differ significantly at 95% level.

PROTEIN NUTRITIVE VALUE

Sunflower proteins, while higher than cereals such as wheat flour, are much lower in lysine content than are legume and animal proteins (Table VII). However, sunflower proteins were rich in other essential amino acids especially the sulfur-containing amino acids.

The protein efficiency ratios (PER) of sunflower flour and concentrate were evaluated with soybean flour and a casein control in rat feeding trials using procedures described previously by Sarwar et al. (19). Each product was the sole source of protein in a 10% protein diet fed to eight weanling male rats during a 4-wk period. Average feed consumption and weight gain on the soybean flour diet exceeded those obtained with sunflower proteins but only the protein efficiency value was significantly higher than that of sunflower flour (Table VIII).

In a second feeding trial with rats, sunflower concentrate was supplemented with lysine and other protein sources in diets which contained a total of 9% protein. Lysine supplementation at 0.4% of the diet improved the feed consumption, weight gain, and PER of the sunflower concentrate diet to levels which were significantly higher than the unsupplemented sunflower and casein diets (Table IX). On the other hand, a 50-50 blend of sunflower concentrate and wheat flour proteins reduced weight gain and PER because lysine was also the first limiting amino acid in wheat protein. The combination of a high lysine legume such as field pea protein (Table VII) in a 50-50 protein blend with sunflower concentrate resulted in very high feed consumption and weight gains for the rats and a PER equivalent to the casein control (Table IX). The combination of sunflower concentrate and defatted ground beef also gave high feed consumption, weight gain, and PER values in the rat-feeding trial. It appeared that sunflower products should not be used as a protein supplement for low lysine food products such as cereals but would provide excellent supplementation for legume and animal protein sources.

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