Food Uses of Sunflower Proteins

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ABSTRACT

Commercial use of sunflower meal as a food product is dependent on the development of low chlorogenic acid cultivars and efficient procedures for dehulling the high oil cultivars and hybrids. Laboratory defatted sunflower flours have high protein contents, bland flavors, white colors at acid pH levels, and contain no antinutritive factors. Functional test data show that sunflower flours and protein concentrates have high salt solubility, oil absorption and oil emulsification. In rat feeding trials, the low lysine level in sunflower proteins has resulted in low protein efficiency ratios for sunflower diets and blends with cereals including bakery products. High weight gains are obtained for sunflower blends with legume and animal proteins, suggesting applications in milk and meat extenders and in soybean-based infant formulas. Heat treatments, mechanical agitation, and emulsifiers were effective in solubilizing 80% of sunflower proteins in extended milk formulations, and the product was given high ratings in taste panel evaluations. Sunflower flour slurries show excellent whippability and foam stability, comparable to that of soybean protein isolate, but lack the ability to form a firm gel. Wieners supplemented with sunflower products have low shrinkage and cooking losses, but rate poorly in organoleptic tests. Texturization of sunflower flour by extrusion cooking gave fibrous chunks which were greyish in appearance, but had a chewy texture, a meat-like flavor, and gave low cooking losses in beef pattie formulations. Spun sunflower protein/casein (1:1) blends are superior to other vegetable proteins in shear strength, swellability and firmness. Sunflower flours are particularly deleterious to bread loaf characteristics. This effect can be partially overcome by autoclaving the flour, concentration of the protein, or addition of gluten, but the protein nutritive value of the supplemented bread is only marginally improved.

INTRODUCTION

Use of oilseed proteins in human and pet foods has expanded markedly during the past fifteen years because of improved processing technology and functional properties in the flours, protein concentrates and isolates. Soybean and gluten products have a commanding lead as vegetable protein supplements, but several other cereals, oilseeds, and legumes show promise as alternate sources of food grade protein. Sunflower proteins in particular have unique organoleptic and functional properties which could expand the range of food uses for concentrated seed proteins. The characteristics, processing, functionality and nutritive value of sunflower flour, concentrate, and isolate have been the subject of recent reviews (1,2). The objective of the present paper is to evaluate the potential food uses for sunflower products with emphasis on constraints which have limited their utilization in commercial food products.

Production patterns of the eight major vegetable oils are summarized in Table I. Dominance of soybean is readily apparent (3). While sunflower oil production is nearly one-half that of soybean, the difference in meal production is essentially ten-fold. In addition, the growth rates of palm, soybean, and rapeseed production are substantially greater than is evident for sunflower, groundnut, and cottonseed. Because of the low yield of sunflower meal during oil extraction, disposal of the protein by-product in the animal feed market is less of a problem in sunflower seed crushing than commonly applies in processing other oilseeds. Generally, the sunflower crusher is under less pressure to find alternate uses for the meal than the soybean and cottonseed processor.

As a result of intensive plant breeding efforts in the USSR, the oil contents of sunflower cultivars have been increased from about 33% to over 50%. These increases have been the result of reducing the hull contents in the seed from 40% to 25%. Current commercial cultivars and F_1 hybrides have seeds in which there is essentially no free air space between the hull and kernel. Traditional methods of cracking and separating the hulls by air classification are no longer feasible due to excessive losses of meat fines in the hull fraction. The throughput of a crushing plant could be increased by 20% if equipment for good continuous dehulling of sunflower seeds were available for commercial use. At the present time, hull-free flour for food development investigations must be produced in laboratory and

TABLE I

World Production of Vegetable Oils and Meals

	Oil production 1975 1,000 tons	Meal production 1975 1,000 tons	Average growth rate 1965-75 % p.a.
Soybean	8,530	16,830	7.3
Sunflower	4,030	1,590	2.7
Groundnut	3,240	2,060	0
Cottonseed	3,010	3,730	2.4
Palm	2,980	---	9.1
Coconut	2,910	320	1.9
Rapeseed	2,650	1,380	5.4
Olive	1,470	---	2.9

TABLE II

Composition of Sunflower Products, %

Protein product	Protein[a]	Fat	Fiber	Ash
Kernel	26.1	56.3	2.5	3.6
Flour	53.0	1.8	3.6	8.2
Concentrate	68.6	1.0	5.1	6.9
Isolate	87.7	0.1	0.5	3.2

[a]N x 5.7.

TABLE III

Protein Nutritive Value of Sunflower Blends with Cereal, Legume and Animal Proteins and Lysine (2)

Protein source	Feed consumption g/rat	Weight gain g/rat	PER[a]
Casein	264	72.8	2.50
Sunflower concentrate	229	51.9	2.00
+ wheat flour	241	36.4	1.34
+ field peas	342	101.7	2.65
+ ground beef	292	92.8	2.82
+ lysine	339	116.7	3.06

[a]Protein efficiency ratios adjusted to casein = 2.50.

pilot plant facilities. It is unlikely that commercial utilization of sunflower proteins in food products can be initiated until a satisfactory method of seed dehulling or meal fractionation has been developed.

PROTEINS AND PHENOLIC ACIDS

Laboratory-prepared samples of dehulled sunflower products are comparable to soybean in protein content but contain higher levels of crude fiber and ash (Table II). Using the nitrogen to protein factor of 5.7, the protein levels in sunflower flours, protein concentrates, and isolates are typically 53, 69 and 88%, respectively (4,5). Globulins constitute 70-80% of the sunflower seed proteins, and this protein fraction exhibits low water solubility below pH 8, but is readily dispersed in dilute salt solutions (6,7,8). In particular, sunflower proteins are highly soluble in low or high concentrations of sodium and calcium chloride, a property which is lacking in soybean and groundnut proteins (9). These salts are common constituents in the aqueous phase of many food systems, including those of ground meats and imitation milk products.

Oxidation of polyphenolic compounds in sunflower flour, autolytically under alkaline conditions or enzymatically by polyphenol oxidase, leads to the development of green and brown colors when the oxidation products bond with sunflower proteins (10,11). The total composition of phenolic compounds in sunflower varies between 3.0 and 3.5 g per 100 g of flour. Chlorogenic and caffeic acids, which have high oxidation potential due to the presence of an acrylic acid group in conjugation with the aromatic ring (12), constitute almost 70% of the total phenolic compounds (13). Sinapic, isoferulic, *p*-coumaric and *trans*-cinnamic acids have also been identified in gas liquid chromatographs of the phenolic constituents. Generally, food applications of sunflower flour are restricted to neutral and acidic products, but protein concentrates, which have been extracted to remove phenolic compounds (14), can be used successfully under alkaline pH conditions (15).

PROTEIN NUTRITIVE VALUE

The nutritive value of sunflower protein concentrate, alone and in equal blends with wheat flour, field peas and ground beef, was evaluated in rat feeding trials (2). The 9% protein diets, which included a casein control and lysine supplementation at 0.4% of the diet, were fed to male weanling rats during a 4-week period (Table III). The weight gain on sunflower concentrate was significantly poorer than on casein, and the blend with wheat flour, which was also deficient in lysine, gave a low protein efficiency ratio (PER). The combinations of sunflower with a high lysine legume such as field peas or an animal protein like ground beef resulted in high feed consumption, weight gain, and PER values. It was concluded that sunflower products should not be used as protein supplements in bakery products of breakfast cereals. However, sunflower proteins appeared excellent for supplementation and dilution of soybean in infant formulas, milk extenders and milk substitutes. Sunflower proteins also have potential as a protein extender for ground meat products.

MILK-LIKE BEVERAGES

Although lower in nitrogen solubility than the flour, sunflower concentrates have the bland flavor and white color which is desired in a product intended for use in extended or simulated milk-like beverages (15). Treatment of the sunflower concentrate slurries with heat (80 C), mechanical agitation (Polytron mixer), and emulsifiers (0.2% carraghenan + gum tragacanth), were effective in solubilizing 80% of the nitrogen at pH 7.2. Blending the extract with cow's milk improved nitrogen solubility, possibly due to the presence of calcium salts. An equal blend of a 3.0% sunflower protein solution with milk had a low color and flavor profile when compared with a similar soybean-milk blend (Table IV). Generally the slight cereal flavor of sunflower was considered to be less unpleasant than the strong beany flavor of soybean which carried over into the soybean-milk blend.

The sunflower-milk blend was equivalent to the soybean-milk beverage in chemical score (Table V). Lysine was the first limiting amino acid in sunflower, while sulfur amino acids were first limiting in cow's milk, soybean, and the soybean-milk blend. Excellent complementation between sunflower and milk resulted in the blend being first limiting in threonine, based on comparisons with the FAO provisional pattern.

FOAMING, THICKENING AND GELATION

In tests of functional properties sunflower proteins were

TABLE IV

Color and Flavor of 3.0% Protein Extract from Sunflower Concentrate and Soybean Flour, and Their Blends with Milk (1:1) (15)

Protein source	Temp. C	Characteristics of 3.0% extract		Characteristics of extract-milk blend	
		Color	Flavor	Color	Flavor
Soybean	25	Yellow-green	Strong-beany	Yellow-white	Strong-beany
Sunflower	25	Grey	Cereal-like	Greyish-white	Slight-cereal
Soybean	70	Light-tan	Slight-beany	Tan-white	Slight-beany
Sunflower	70	Grey-white	Slight cereal, no after taste	Milky-white	Slight cereal, no after taste

TABLE V

Essential Amino Acid Contents of Sunflower and Soybean Proteins and Their Blends with Milk (15)

Amino acid	Cow's milk	Sunflower concentrate	Soybean flour	Sunflower milk (1:1)	Soybean milk (1:1)
	Amino acid (g amino acid/100 g protein)				
Isoleucine	4.7	3.6	4.9	4.2	4.8
Leucine	9.5	5.5	8.7	7.5	9.1
Lysine	7.8	2.7[a]	6.5	5.8	7.2
Methionine + cystine	3.3[a]	3.6	3.0[a]	3.5	3.2[a]
Phenylalanine + tyrosine	10.2	6.2	8.3	8.2	9.2
Threonine	4.4	3.0	3.7	3.7[a]	4.1
Tryptophan	1.4	1.2	1.3	1.3	1.4
Valine	6.4	4.4	5.7	5.4	6.1
	Chemical score				
	94.3	49.1	85.7	90.5	91.4

[a]First limiting amino acids relative to the FAO Provisional Pattern (1970).

TABLE VI

Viscosity of 10% Protein Slurries before and after Heating at 90 C for 45 Min (18)

Protein product	Apparent Brookfield viscosity: Before heating	After cooling	Characteristics of final product
	cps x 1,000		After cooling
Soybean flour	1	45	smooth fluid
concentrate	6	>166	granular fluid
isolate	3	>166	firm gel
Sunflower flour	1	69	smooth fluid
concentrate	3	>166	granular gel
isolate	1	49	syneresis

shown to have fair water absorption and high oil emulsification characteristics (5). These properties may be associated with the excellent whippability and foam stability of sunflower proteins. The initial foam volumes of sunflower flour, concentrate and isolate were comparable to those of Promine D, a soybean isolate with good foaming characteristics. The foam stabilities of the sunflower flour and isolate during the 2 hr rest period were similar to those of the soybean isolate, while soybean concentrate produced foams with low initial volumes and poor stability. Huffman et al. (16) reported that foam volumes and stability were optimum at pH 9 and lowest at pH 5. Unfortunately, the foams from sunflower flour slurries were green at pH 9. It is apparent that plant breeding for low chlorogenic acid in the seed must be initiated before the potential of sunflower proteins as functional and nutritional ingredients in foods can be realized.

Slurries of soybean globulins exhibit the phenomena of thickening and gelation when heated in sealed containers (17). This property is important in wiener and sausage emulsions as well as in custard-type puddings and sauces. Initial viscosities of the 10% slurries of soybean and sunflower products were positively correlated with the high, but variable, viscosities after heating and cooling the slurries (Table VI). Soybean concentrate, soybean isolate, and sunflower concentrate gave high final viscosities, but only the latter two products demonstrated the gelation property. The sunflower isolate proteins coagulated during heating and separated from the liquid phase. Promine D was the only product to form an attractive translucent gel after cooling.

MEAT APPLICATIONS

Sunflower flour and concentrate were evaluated as direct additives to commercial wiener mixes (19). Soybean flour and concentrate (Promosoy) were included for comparative purposes, and all supplements were added on a constant protein basis to increase the protein level from 12% in the control to 14% in the supplemented wieners. All supplements increased water absorption of the cooked wiener by 2-3%, but only sunflower products reduced fat losses during cooking. Wieners supplemented with sunflower flour were soft in texture and light in color, but the cooking water was light green due to an alkaline pH. Sunflower concentrate was rated by a taste panel as comparable to the control in firmness, flavor, texture, and preference.

A second experiment was conducted in which sunflower flour and concentrate were added at the 25% replacement level in wieners, bologna, mock chicken loaf, and pickle and pimento loaf (20). Physical and organoleptic evaluations demonstrated that poor water-holding capacity and softness were characteristic of both sunflower-supplemented meat products.

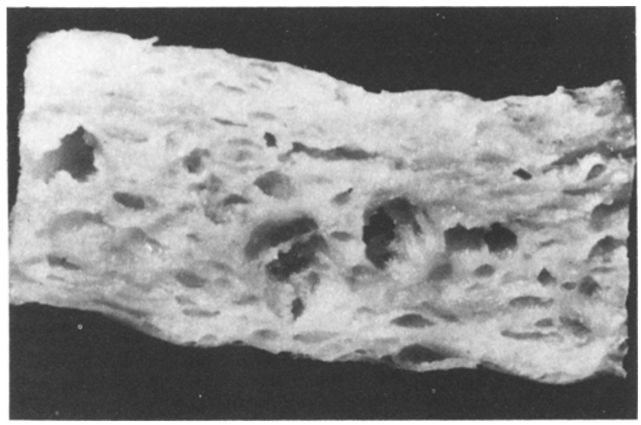

FIG. 1. Light micrograph of extrusion-cooked sunflower flour, magnification 2.5 x (20).

The sunflower products were then texturized by extrusion through a Brabender laboratory extruder and, after hydration, were incorporated into meat patties for cooking and taste panel evaluations (20). Light micrographs of longitudinal cross-sections of the textural chunks showed a porous structure with continuous layers of protein enclosing the air spaces (Figure 1). Scanning electron micrographs demonstrated the presence of a laminated sheet structure which was disrupted in certain areas, perhaps due to pressures developed during extrusion (Figure 2). Under higher magnification, some areas exhibited a distinct fibrous structure. Taste panels found the textured sun-

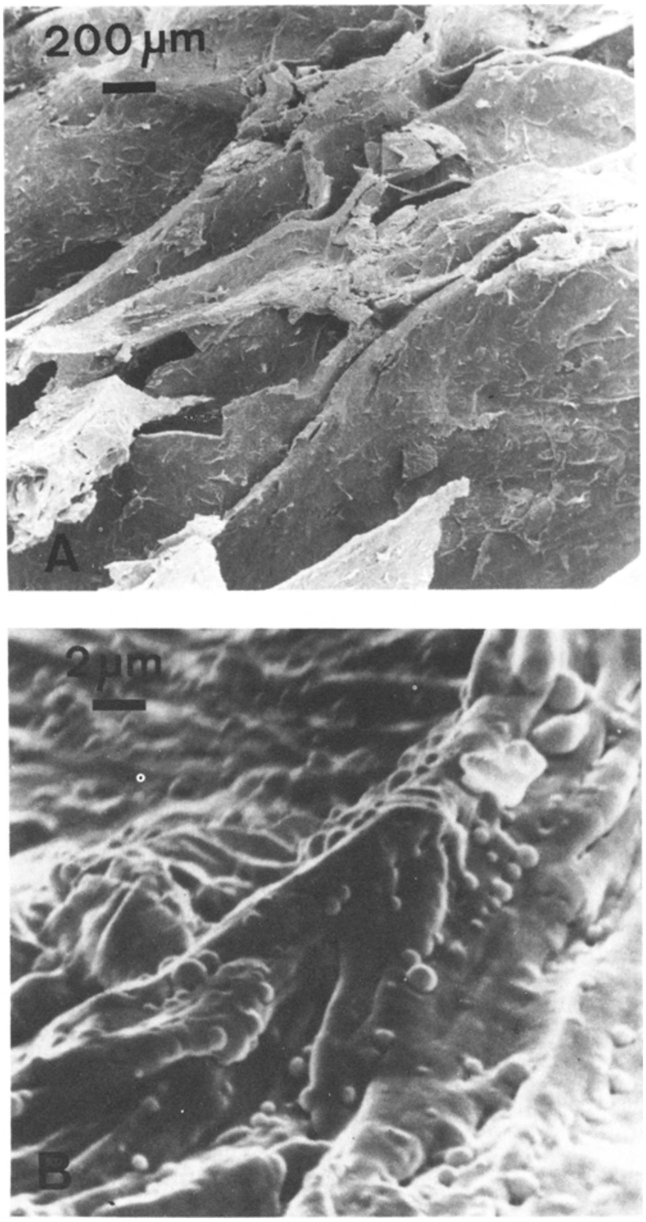

FIG. 2. Scanning electron micrographs of the laminated sheet (A) and fibrous (B) structure of extrusion-cooked sunflower flour (20).

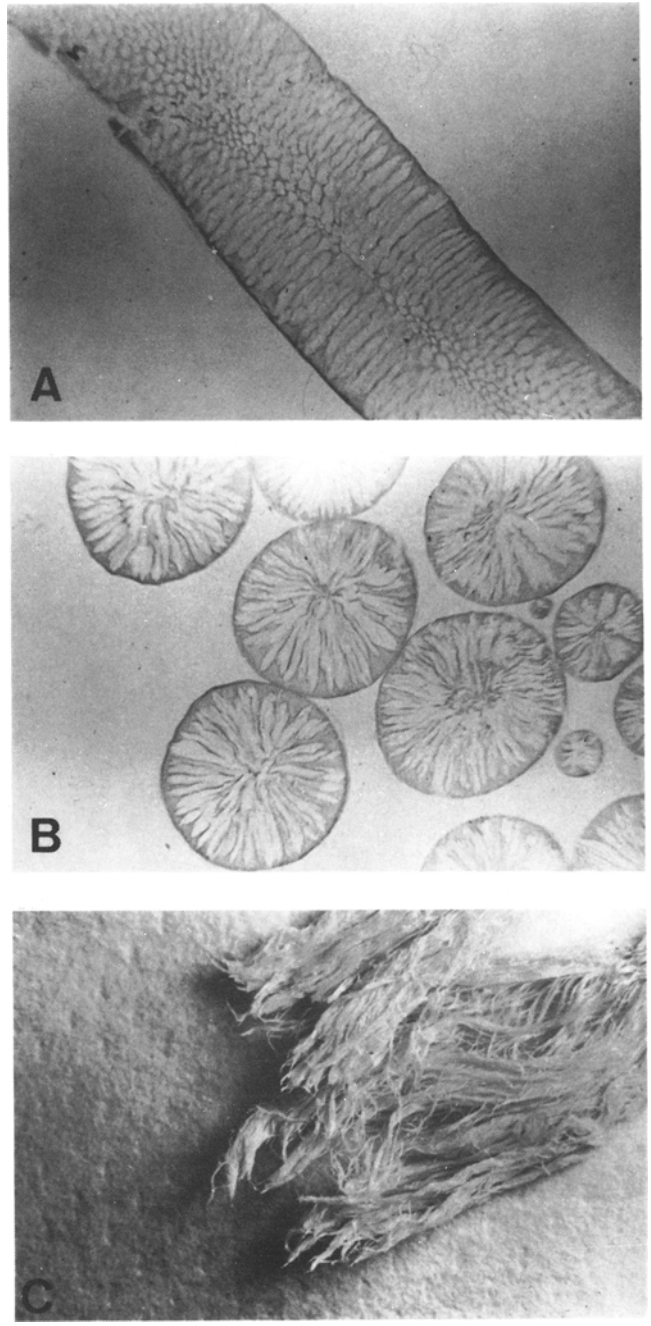

FIG. 3. Light micrographs of longitudinal (A) and cross (B) sections of individual spun sunflower protein/casein (1:1) fibers and bundles (C) of parallel ordered fibers.

flower products to be chewy and meat-like, but greyish colors and slight cereal or bitter flavors were noted. It appeared that sunflower flour was superior to the concentrate in ease of extrusion and fiber formation, but there were greater problems with color and flavor. Development of low chlorogenic acid sunflower cultivars would greatly enhance the prospects for utilizing sunflower flour in ground meat products.

Schmandke and Hartmann (21) have published a series of papers on the development of spun sunflower protein/casein (1:1) fibers. Characteristics of individual spun fibers are illustrated in longitudinal and cross section, and in bundles of parallel ordered fibers containing heat-coagulated binders (Figure 3). The shear strength, swellability and firmness of these fibers were superior to field bean protein/casein (1:1) fibers (22) and rapeseed protein/casein (1:1) fibers (23). When treated with dialdehyde starch, the bundles were comparable in texture, as well as nutritive value, to minced meat.

BAKERY PRODUCT

Talley et al. (24) substituted 3, 17 and 30% of sunflower meal for wheat flour in protein-supplemented bread and demonstrated severe reduction in loaf volume for the latter two treatments. The 17 and 30% formulas produced compact, dense and dark loaves that would be unacceptable to the consumer. Rooney et al. (25) also found that 8 and 15% incorporation of sunflower flour into wheat bread formulae resulted in substantial reductions in loaf volume, crumb characteristics, and specific volume, especially at the higher level. Autoclaving sunflower flour for 1 hr at 120 C before blending with the wheat flour at the 8% level gave acceptable loaves, but mixing characteristics and loaf color were inferior to the control and cottonseed-peanut- and sesame-supplemented bread. Ling and Robinson (26) produced the best loaves when 5% unheated and 5% autoclaved sunflower flour was blended with wheat flour. Acceptable bread was also produced by using 5% of isolated sunflower protein. Satisfactory cookies could be made with 15% unheated or 30% heated sunflower flour in the blend.

TABLE VII

Protein Ratings for Bread Supplemented With Sunflower, Soybean, Fababean and Field Peas (28)

Bread supplementation	Supplementation level %	Moisture 1 hr after baking %	Protein dry basis Nx6.25 %	Protein in 150 g bread g	PER[a]	Protein[b] Rating
Wheat control	0	28.1	15.9	17.2	1.09	18.7
Sunflower conc.	12	29.9	23.2	24.2	1.27	30.7
Soybean flour	15	32.1	21.8	22.2	1.69	37.5
Fababean conc.	15	25.6	23.3	26.0	1.67	43.4
Field pea conc.	15	28.5	22.3	23.9	1.81	43.2
Sunflower + lysine	15	29.9	23.9	25.1	2.14	53.7

[a]Protein efficiency ratio adjusted to 2.50 for casein.
[b]Protein rating = PER x g of protein in average daily intake (150 g).

Flour blends containing 12% sunflower concentrate were combined with 2% vital gluten and 1% dough conditioner in order to restore bread quality (27). Determination of the nutritive value of this bread in comparison with soybean-fababean- and field pea-supplemented bread shows the inferiority of sunflower-wheat protein blends for rats (Table VII). Despite the high protein level in the bread (23.2% dry basis), the PER for the sunflower-supplemented bread was only 1.27 compared to 1.09 for the wheat bread control and 1.7 to 1.8 for the other supplemented breads. Lysine supplementation of the sunflower bread formula (4.0 g L-lysine/100 g protein) produced breads with high PER and protein ratings.

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