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COMPOSITION, COLOR AND FUNCTIONAL PROPERTIES OF PROTEIN INGREDIENTS PREPARED FROM SUNFLOWER SEED DEFATTED FLOUR TREATED WITH ACIDIC ETHANOL

M. M. Zaghloul
Food Sci. Dept.., Fac. of Agric. Minia Univ., El-Minia, Egypt.

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ABSTRACT

Eighty mesh sunflower seed defatted flour (DF) was prepared from manually dehulled and coarsely ground seeds after oil extraction with n-hexane. This flour was treated with acidic ethanol to remove chlorogenic acid (CGA). The effect of such treatment on the amino acid composition of the DF and on the chemical composition, color and functional properties of the DF, protein concentrate (PC) and protein isolate (PI_S) prepared from treated DF were evaluated using soybean DF as a reference. The results indicated that sunflower kernels contained 54.41 oil, 27.73 protein, 3.99 ash, 3.36 fiber and 10.50% carbohydrates (Dry basis) and the extraction of oil led to an increase in all other constituents in the obtained DF, especially protein content. There was no substantial difference in the chemical score values of both untreated and treated DF of sunflower seed and lysine was the most limiting amino acid in both of them, whereas sulphur amino acids were the most limiting in the case of soybean DF. The PI_S prepared from untreated sunflower DF appeared decidedly dark and brown to the naked eye and the change of its color was extreme (that's why, it was omitted in the study of functional properties), while all other samples appeared light in color and similar to each other. These results were confirmed with the color analysis. The proteins of sunflower DF_S were substantially less soluble at acidic pH than soybean proteins, whereas at alkaline pH, especially at pH 9 and above, all the three flours were highly soluble. As compared to sunflower DFs, PC had fairly sharp solubility minimum around pH 5, while PI_S showed a solubility profile of u-shaped pattern similar to that of soybean DF.

Sunflower DF treated with acidic ethanol had good functional properties. This flour had an oil absorption capacity (OAC), oil emulsification capacity (EC) and foaming properties better than those of soybean DF in addition to gelation properties similar to soybean DF. On the other hand, the PC and PIs prepared from this flour also exhibited good functional properties in terms of water absorption capacity (WAC), OAC, EC and foaming as well as gelation properties.

Considering the good functional properties, the high protein content and the excellent amino acid composition in addition to possibility of preparation of accepted white color isolate, sunflower DF treated with acidic ethanol as well as the PC and PI_S prepared may be successfully used in many food formulations as sources of protein and as good functional ingredients.

INTRODUCTION

It is well known that, Egypt is facing a shortage of edible oil and also of low price protein. Oil seeds represent a major potential for increasing oil and protein supplies but more attention should be given to the importance of oilseed meals and their other protein ingredients such as protein concentrates and protein isolates as sources of supplementary protein of high quality food for people. Steps have to be taken to bring large areas of land under oilseeds production (peanut, sesame, sunflower, soybean, cotton and safflower seeds) and to improve productivity through improved seeds, inputs, pest control and better agricultural production to boost up the oil and protein production.

Sunflower (*Helianthus annus* L.) is one of the major sources of vegetable oil in the world, its seeds contain nearly 25% protein and the defatted meal is rich in protein (about 55%). Because of its high nutrient content and the absence of any known toxic or antinutritional factors, sunflower meal represents a promising new source of human protein food (Sosulski, 1979). But, the major problem in the utilization of sunflower seed protein ingredients as a food supplement is their dark greenish-brown color due to the oxidation of chlorogenic acid (CGA) under alkaline conditions and to produce a food-grade product from sunflower meal, it needs to remove CGA, the major polyphenolic constituent of the seeds responsible of the darkening of protein during the alkaline extraction (Lusas, 1985). However, many publications on

the removal of CGA from either kernels or defatted meals in order to obtain white color protein isolates from sunflower seeds (Sabir *et al.*, 1973 a, b; Fan and Sosulski, 1976; Sodini and Canella, 1977; Rahma and Narasinga Rao, 1979, 1981a; Taha *et al.*, 1982; Lusas, 1985 and Vaintraub and Bastryging, 1989) including washing with acidic butanol or ethanol.

The use of plant protein as an ingredient in food formulation is dependent on their functional properties and for their application, it is necessary that their functional properties should be investigated and if necessary, desirable functional properties should be incorporated in the protein through modification (Were *et al.*, 1997 and Bora, 2002).

However, sunflower proteins have been studied for their isolation and characterization (Rahma and Narasinga Rao, 1979 & 1981b), effect of enzymatic hydrolysis (Cai *et al.*, 1996), wet and dry heating (Aruna Venktesh and Prakash, 1993), succinylation (Schwenke and Rauschal, 1983) and acetylation (Canella *et al.*, 1979) on their physicochemical properties. Gueguen *et al.* (1996) studied the emulsifying and foaming properties of the 2S albumin of sunflower.

The present investigation deals with the preparation of an edible defatted flour (DF) from sunflower seeds. This flour was treated (DF-t) with acidic-ethanol for the removal of chlorogenic acid (CGA) and then used for the preparation of protein concentrate (PC) and protein isolate (PI_S) which was also prepared from untreated flour by the traditional alkali extraction-acid precipitation procedure. The proximate composition, the color values and the functional properties of these protein ingredients were determined. The amino acid composition of the defatted flours (both treated and untreated) was also determined. For purpose of comparison, soybean defatted flour was used in the study as a reference.

MATERIALS AND METHODS

Materials:

Sunflower seeds (*Helianthus annus* L.), an oil type authentic variety "Miak" grown in Sohag Governorate during the year 2005 were obtained (10 Kg) from the Seed Department, Ministry of Agriculture, Giza, Egypt. The seeds were manually cleaned and kept in

cloth bags at RT until used. Hesco defatted soy flour from Hesco, Watertown, South Dakota, USA. Corn oil (Crystal brand) was purchased from the local market.

Methods:

Preparation of defatted flour (DF): was carried out following the procedure of Cai *et al.* (1996). The seeds were dehulled manually, coarsely ground in an electric grinder (Moulinex-France) and extracted with n-hexane until the oil content was less than 1.0% in a large soxhelt apparatus. The DF was desolventized by air-drying for 72 hours at 25-30°C and then pulverized to obtain fine flour of 80 mesh and stored in a desiccator at 5°C (Huffman *et al.*, 1975). Hesco soybean DF was further defatted to assure an oil content less than 1.0% and was also obtained in the same manner like sunflower DF to be used as a reference sample.

Preparation of sunflower protein concentrate (PC): DF was dispersed in distilled water (1:10, w/v) by stirring constantly for 30 min with a magnetic stirrer. The pH was adjusted to pH 5.0 using 1.0 N HCl and extraction continued by stirring for another 30 min. The dispersion was then centrifuged at 4000 rpm for 15 min (using Beckman Model J-21C centrifuge-USA) and the precipitate was resuspended in distilled water to a heavy suspension and adjusted to pH 7.0 using 1 N NaOH and freeze-dried (Lusas, 1985).

Preparation of sunflower protein isolate (PI_S): was made according to the procedure reported by Rahma and Narasinga Rao (1979) with slight modification. The DF (100 g) was mixed with 1 liter of water and the pH adjusted to 10 by the addition of 1 N NaOH solution. It was stirred for 1 hr, centrifuged at 4000 rpm for 20 min and the pH of the supernatant adjusted to pH 5. The resultant precipitates were removed by centrifugation adjusted to pH 7 and freeze-dried.

Removal of chlorogenic acid (CGA): was carried aut according to the procedure described by Rahma and Narasinga Rao (1979). The DF was packed into a column and washed twice with 0.001 N HCl (pH 5). It was followed by washing with 50% ethyl alcohol until the washings did not develop yellow color with NaOH. The flour was then blended with cold distilled water. It was centrifuged at 4000 rpm for 15 min the residue washed with diethyl ether and dried in the air at room

temperature (25-30°C). All the extraction operations were done in the cold. The DF, thus treated did not give a positive test for CGA and its discoloration at pH 10 did not occur.

Chemical analysis: Moisture, crude fat, crude protein (N x 6.25), crude fibers and ash contents were determined according to standard AOAC (1995) methods. Carbohydrate was calculated by difference. Amino acids composition was determined using a Beckman amino acid analyzer model 119 CL (USA) according to Spackman *et al.* (1958) after hydrolysis with 6 N HCl at 110°C for 24 hours. Tryptophan was determined colorimetrically after alkaline hydrolysis with 4.2 N NaOH at 110°C for 24 hours according to the method described by Blauth *et al.* (1963). Amino acid score of proteins was calculated as % of the scoring pattern suggested by FAO/WHO (1973).

Color: was measured on a color difference meter (model color Tec-PCM, USA) using different color parameters (lightness (L); redness (a) and yellowness (b)) according to Francis (1983). The average of three determinations ± SD was reported for each value.

Functional properties:

Nitrogen solubility. was determined according to Rahma and Narasinga Rao (1979) and Lawal *et al.* (2007) with slight modification. To one gram of defatted flour or to a half gram of either protein concentrate or isolate, 20 ml of distilled water were added and the pH of the suspension adjusted to the desired value by adding 1 N HCl or 1 N NaOH. The suspension was then shaken for 1 hr at room temperature (25°C), centrifuged at 4000 rpm for 30 min and the pH of the supernatant noted. Aliquots of 10 ml were taken for nitrogen estimation by the kjeldahl method. The percentage of nitrogen was calculated and plotted against corresponding pH values in the pH range 1-11.

Bulk density: was determined according to Bencini (1986) by weighing 50 ml of the powdered sample and expressed as g/ml.

Water absorption capacity (WAC): expressed as the amount of water (g) retained by 100g of the residue after giving the correction for soluble solids.

Oil absorption capacity (OAC) expressed as the amount of oil (g) bound by 100g of the sample.

Gelation properties expressed as the least gelation concentration (LGC) were determined as described earlier (Zaghloul *et al.*, 2005).

Emulsification capacity (EC): Two grams of the sample were suspended in 100 ml distilled water in a blender jar and blended for 30 sec at low speed using "National super blender-Japan". After complete dispersion, corn oil was added continuously at a rate of 0.5 ml/sec by burette while blending until the emulsion break point was visually reached. EC was expressed as ml oil emulsified by 100 ml of 2% (w/v) sample suspension (Ihekoronye, 1986).

Foaming capacity (FC) and Foam stability (FS): 100 ml of distilled water were added to 3 g sample and the mixture whipped at highest speed for 5 min in "National super blender-Japan" and poured into a 250 ml measuring cylinder. The volume of foam at 30 sec was recorded and the percent volume increase was expressed as FC. The foam stability was determined by recording the decrease in volume of foam as percentage of the initial foam volume as a function of time up to a period of 120 min (Lin *et al.*, 1974 and Aruna Venktesh and Prakash, 1993).

RESULTS AND DISCUSSION

Proximate composition:

The proximate composition (on dry weight basis) of the manually dehulled kernels and the protein ingredients prepared from sunflower seeds is presented in Table 1. The data showed that kernels contained 54.41% fat, 27.73% protein, 3.99% ash, 3.36% fiber and 10.50% carbohydrates. Extraction of oil led to an increase in all other constituents in the obtained defatted flour "DF" (Less than 1.0% fat) and the major increase was in protein content (58.05%). This showed that sunflower seed DF is a good source of protein. The protein content was 72.23% and 97.58% in the protein concentrate (PC) and isolate (PI_S) prepared from treated DF, respectively. Ash content decreased in both PC (2.32%) and PI_S (1.89%) compared to the DF (6.50%) from which, they were prepared. Both fiber and carbohydrates were completely absent in the PI_S. This could be attributed to the removal of water-insoluble polysaccharides as well as the water-soluble sugars

during the preparation of PI_S. Soybean DF had a protein content of 55.27%, lower than that of sunflower DF by about 3.0 and 5.0% and a carbohydrate content of 31.99% which was higher than that of sunflower DF by about 4.0 and 5.0% for both untreated and treated flour, respectively. When compare the proximate composition of the treated-DF for the removal of chlorogenic acid with that of the untreated-DF, the treated flour had some decreases in fat content (from 0.95 to 0.73%), ash (from 7.84 to 6.5%) and carbohydrates (from 27.86 to 26.65%), whereas had some increases in protein (from 58.05 to 60.02%) and crude fiber (from 5.30 to 6.09%). This could be due to the washing process with acid water, followed by alcohol, which may led to some loss in fat, ash and carbohydrates by washing them out.

Table 1: Proximate composition* of kernels, defatted flour (DF); protein concentrate (PC) and protein isolate (PI_S) prepared from treated sunflower DF (as % on dry weight basis).**

Constituents (%)	Samples of protein ingredients from sunflower seed					Soybean DF***
	Kernels	DF (untreated)	DF** (treated)	PC	PI_S	
Moisture	4.80±0.1	5.6±0.1	4.70±0.1	5.30±0.1	5.10±0.1	6.80±0.1
Crude Fat	54.41±0.2	0.95±0.0	0.73±0.0	0.74±0.0	0.53±0.0	0.98±0.0
Protein(T.Nx6.25)	27.73±0.2	58.05±0.3	60.02±0.3	72.23±0.3	97.58±0.3	55.27±0.3
Ash	3.99±0.1	7.84±0.2	6.50±0.2	2.32±0.1	1.89±0.1	6.26±0.2
Fibers	3.36±0.1	5.30±0.2	6.09±0.2	6.55±0.2	0.0	5.50±0.2
Carbohydrates (by difference)	10.50±0.2	27.86±0.3	26.65±0.3	18.16±0.2	0.0	31.99±0.3

* Means of three determinations ± SD.

** Treated with acidic ethanol for removal of chlorogenic acid (CGA).

*** Used as a reference.

Amino acid composition and chemical score:

The amino acid composition of both untreated and treated sunflower seed DF as well as soybean DF was determined and expressed as g amino acid/100g protein (Table 2). The results indicated that glutamic acid (18.25, 20.84 and 21.03), followed by aspartic acid (11.52, 9.60 and 9.72), arginine (7.06, 9.32 and 9.05) and leucine (7.25, 6.68 and 6.78) were the dominant amino acids, while

methionine (1.32, 2.28 and 2.34), followed by cystine (1.42, 1.52 and 1.58), tryptophan (1.62, 1.56 and 1.55) and histidine (2.40, 2.64 and 2.62) were found in small amounts in the DF of soybean, sunflower untreated and treated, respectively. These types of defatted flours had the values of 97.32, 97.30 and 98.21 for total amino acids and the essential amino acids constituted 35.53, 33.19 and 33.66%, while the non-essential amino acids constituted 64.47, 66.81 and 66.34% of the total amino acids in the same order, respectively. These data showed that, treatment of the DF of sunflower seeds with acidic ethanol for the

Table2: Amino acid composition (g/100g protein) of sunflower seed defatted flour (DF) "untreated and treated with acidic ethanol" and soybean DF.

Amino acids (AA)	Sunflower seed (DF)		Soybean (DF)**
	untreated	treated	
Aspartic acid	9.60	9.72	11.52
Threonine*	3.60	3.86	4.12
Serine	4.04	4.21	5.20
Glutamic acid	20.84	21.03	18.25
Proline	4.20	4.22	5.20
Glycine	5.31	5.54	4.14
Alanine	4.42	4.50	4.20
Cystine	1.52	1.58	1.42
Valine*	5.12	5.23	4.75
Methionine*	2.28	2.34	1.32
Isoleucine*	4.22	4.48	4.60
Leucine*	6.68	6.78	7.25
Tyrosine	3.12	2.68	3.35
Phenyl alanine*	4.85	4.96	4.82
Histidine	2.64	2.62	2.40
Lysine*	3.98	3.86	6.10
Arginine	9.32	9.05	7.06
Tryptophan*	1.56	1.55	1.62
Total (AA)	97.30	98.21	97.32
Essential (EAA)	32.29	33.06	34.58
EAA as % of TAA	33.19	33.66	35.53
Non-essential AA (NEAA)	65.01	65.15	62.74
NEAA as % of TAA	66.81	66.34	64.47

* Essential A.A.

** Used as a reference.

removal of chlorogenic acid did not affect the percentage of the essential amino acids in the protein and this percentage was slightly higher (by about 2%) in the protein of soybean DF, compared with that of either untreated or treated sunflower seed DF.

Table 3 shows the chemical score values of the flour samples. In sunflower seed, lysine had the least values of (72.36 and 70.18%), followed by threonine (90 and 96.50%) and leucine (95.43 and 96.86%) for both untreated and treated DF, respectively, while, the rest of essential amino acids values ranged between 102 (for valine) and 156% (for tryptophan) as percentage of the values of FAO/WHO pattern.

Table 3: Essential amino acid scores (chemical score) of sunflower seed defatted flour (DF); "untreated and treated with acidic ethanol" and soybean DF.

Essential amino acids (E.A.A.)	FAO/WHO pattern (1973)	Chemical scores (% of FAO/WHO)		
		Sunflower Seed (DF)		Soybean** (DF)
		Untreated	Treated*	
Lysine	5.50	72.36	70.18	110.90
Tryptophan	1.00	156.00	155.00	162.00
Isoleucine	4.00	105.50	112.00	115.00
Leucine	7.00	95.43	96.86	103.57
Aromatic A.A. (Phe + Tyr)	6.00	132.83	127.33	136.17
Threonine	4.00	90.00	96.50	103.00
Valine	5.00	102.40	104.60	95.00
Sulphur A.A. (Met + Cys)	3.50	108.57	112.00	78.29

* For removal of CGA, ** Used as a reference.

In the case of soybean flour, sulphur amino acids (methionine + cystine) had the least chemical score value of 78.29%, followed by valine (95%), while the rest of the essential amino acids had values over 100% and ranged between 103 (threonine) and 162% (tryptophan). These data clearly showed no substantial difference in the chemical score values of both untreated and treated defatted flours of sunflower seed and lysine was the most limiting amino acid in both whereas, sulphur amino acids was the most limiting in the case of soybean defatted flour. These results are in agreement with these of

Smith (1971) and Lusas (1985) who reported that, lysine was the first limiting essential amino acid in sunflower meal, whereas it was methionine in soybean meal and since sunflower meal was higher in methionine content but lower in lysine, They indicated that advantages could be gained by feeding mixtures of meals.

Color evaluation:

Treated DF of sunflower seed was used for the preparation of protein concentrate (PC) and protein isolate (PI_S), whereas untreated DF was used for the preparation of PI_S to evaluate the effect of the alkaline condition during preparation on the color. The color analysis of these protein ingredients along with soybean DF (for comparison) is presented in Table 4. The PI_S prepared from untreated DF appeared decidedly brown to the naked eye, unlike all other samples, which appeared light in color and similar to each other. The results confirmed that the hue of the PI_S prepared from untreated DF tended towards greenish-brown and was less luminous than other samples. This isolate had color values of L (42.72%), a (-4.38) and b (13.26). The data showed that the two types of DF from sunflower seed (untreated and treated) were very similar and highly comparable in their color values with soybean DF. The PC had the color values of L (77.14), a (2.5) and b (9.20) while, the PI_S had the values of L (74.76), a (2.58) and b (9.38) compared to the values of L (82.30), a (1.72) and b (8.74) for the corresponding treated DF from which they were prepared. These results indicated some decrease in lightness and little increase in yellowness and redness in both PC and PI_S prepared from treated DF, although could not be observed with naked eye. This could be due to Maillard reaction during processing but not due to the oxidation of chlorogenic acid as in case of PI_S prepared from untreated flour where the change of its color was extreme. Taha *et al.* (1982) reported that the slightly brown color of the obtained protein isolate could be due to Maillard reaction during processing and drying.

Table 4: Color evaluation* of defatted flour (DF) "treated and treated with acidic ethanol", protein concentrate (PC) and protein isolate (PI_S) of sunflower seed.

The protein ingredient samples	L	a	b
Soybean DF	82.68	1.68	8.75
Sunflour seed:			
DF	82.26	1.78	8.76
DF-t	82.30	1.72	8.74
PC-t(1)	77.14	2.50	9.20
PI_S-t(1)	74.76	2.58	9.38
PI_S(2)	42.72	-4.38	13.26

* Each value is an average of two determinations.
(1) Prepared from treated defatted flour (DF-t).
(2) Prepared from untreated defatted flour (DF).

Functional properties:

Protein isolate, prepared from untreated sunflower seed DF by the traditional alkali extraction-acid precipitation procedure was omitted in the study of functionality due to its an unacceptable color.

Protein solubility: Protein solubility profiles of untreated/ treated sunflower seed and soybean defatted flours (DF), in water at various pH values are shown in Table 1. The proteins of sunflower DF (either treated or not) were substantially less soluble at acidic pH than soybean proteins, whereas at alkaline pH, especially at pH 9.0 and above, all the three flours were highly soluble, indicating that, it is possible to produce protein isolates by alkaline extraction, followed by precipitation at the pH of minimum solubility. However, the pH of minimum solubility in sunflower DF, ranged between pH 3.0 and pH 6.0 with an isoelectric point (PI) of pH 5.0, whereas, soybean DF had a sharp solubility minimum, between pH 4.0 and pH 5.0 with PI of pH 4.5. As compared with either soybean DF or sunflower treated DF, the untreated flour had more protein in the solution at the isoelectric range. The protein solubility profiles of both the protein concentrate (PC) and protein isolate (PI_S) prepared from treated DF are also shown in Fig. 1. Like treated flour, PC had fairly sharp solubility minimum around pH 5.0 compared with the broad range of minimum solubility of the

untreated DF. On the other hand, PI_S showed a solubility profile of u-shaped pattern similar to that of soybean DF and to many profiles reported in the literature for oilseed proteins (McWatters *et al.*, 1976; McWatters and Holmes, 1979a,b and Lawal *et al.*, 2007). Protein isolate had higher solubility values than concentrate, treated or untreated DF at pH 6.0 and above and at pH 3.0 and lower, while had higher solubility values than soybean DF at pH 8.0 and above. These results are in agreement with those of Gheyasuddin *et al.*, 1970; Mattil, 1971; Canella *et al.*, 1979; Rahma and Narasinga Rao, 1979 and Schwenke and Rauschal, 1983 regarding the solubility behavior of sunflower seed proteins.

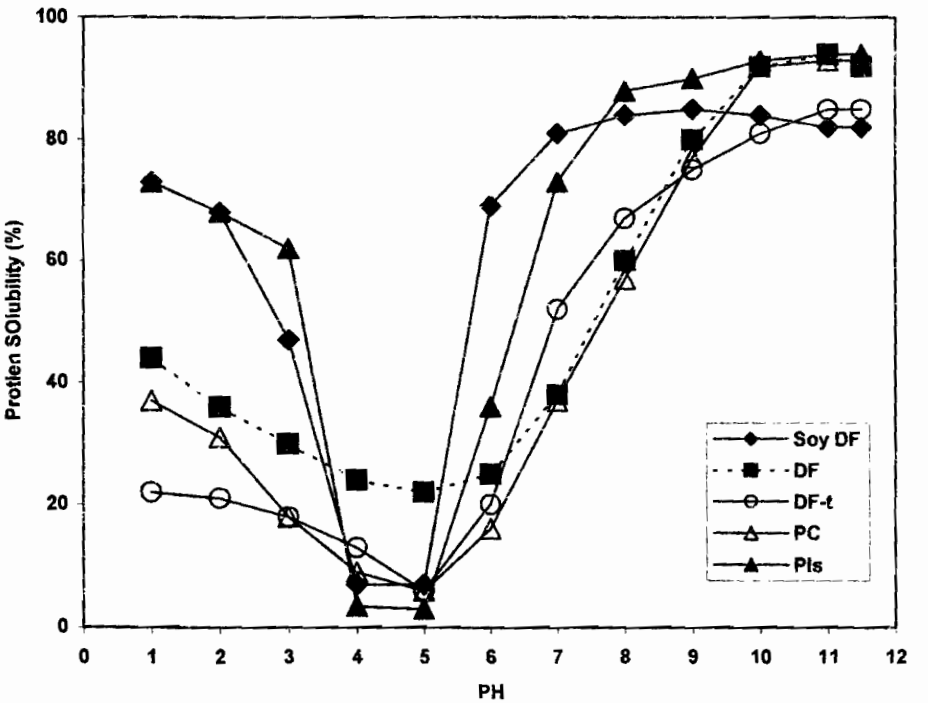

Fig. 1: Protein solubility profiles of defatted flours "untreated (DF) and treated (DF-t) with acidic ethanol", protein concentrate (PC) and protein isolate (PI_S) of sunflower seed and soybean DF (as a reference).

Properties of protein prepared from defatted sunflower seeds

Table 5 illustrates the values of bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC), emulsification capacity (EC), foaming capacity (FC) and gelation, expressed as least gel concentration (LGC) of defatted flours (DF_S), protein concentrate(PC) and isolate (PI_S) prepared from treated sunflower seed DF. Bulk density (BD) of acidic ethanol treated DF (0.284 g/ml) showed an increase compared to the untreated DF (0.264 g/ml). Similar increase in BD of solvent treated seed flours and proteins was observed by other workers (Kinsella, 1976; Wang and Kinsella, 1976; and Aruna Venktesh and Prakash, 1993). Soybean DF showed BD (0.309 g/ml) lower than PI_S (0.318), but higher than the DF_S (either treated or untreated) and PC (0.292 g/ml) of sunflower seed. BD increased with the increase in protein content of the protein ingredients prepared from sunflower seed and this agreed with those obtained by Ihekoronye (1986) for peanut DF, PC and PI_S.

Water absorption capacity (WAC): Acidic ethanol treated DF exhibited a lower WAC (202 g/100g sample) compared to the untreated DF (228) whereas, both exhibited lower values compared to that of soybean DF (290). Similar observations were reported by Aruna and Prakash (1993), who studied the effect of wet heating, dry heating and washing with acidic butanol on the functional properties of the total proteins of sunflower. They reported a decrease in the WAC of the flour due to the acidic butanol treatment and this decrease could possibly be due to protein aggregation, thus decreasing the surface area exposed to the water phase. The higher WAC of soybean DF compared to both treated and untreated sunflower DF may suggest that soy proteins are more hydrophilic in nature than the sunflower proteins. The WAC value (340 g/100g) of sunflower PC was the highest, followed by that of PI_S (306) compared to DF samples. These results suggest that DF and PC have some hydrophilic constituents like carbohydrates, which bind more water than the protein.

Table 5: Functional properties* of the defatted flour "untreated (DF) and treated (DF-t) with acidic ethanol", protein concentrate (PC) and protein isolate (PI_S) of sunflower seed and soybean DF (as a reference).

The protein ingredient samples	B D g/ml	WAC g/100g	OAC g/100g	EC ml oil	FC % vol. increase	Gelation LGC** (% w/v)
Soybean DF	0.309±0.005	290±5	192±2	120±5	78±4	10±0
Sunflower seed:						
DF	0.264±0.003	228±3	294±3	242±5	212±8	10±0
DF-t	0.284±0.004	202±3	238±3	228±5	236±8	10±0
PC (1)	0.292±0.005	340±5	376±2	248±5	254±10	12±0
PI_S (1)	0.318±0.005	306±5	388±2	257±6	263±10	14±0

* Each value is an average of three determinations ± SD.

** The concentration at which, the sample from inverted test tube did not fall down or slip.

(1) Prepared from treated defatted flour (DF-t).

These results are in the same trend with those of Sosulski and Fleming (1977) who obtained WAC values of 240, 180 and 390 g/100g for soybean DF, sunflower DF and PC, respectively. They reported that soybean proteins have higher WAC than their sunflower seed counter parts.

Oil absorption capacity (OAC): The data in Table 5 clearly show that soybean DF had the least value of OAC (192) compared to sunflower untreated DF (294), treated DF (238), PC (376) and PI_S (388 g oil/100g).

Treated DF exhibited lower OAC than the untreated DF. The data also showed that for all the studied sunflower protein ingredients, the OAC values were extended with the increase in protein content from the flour to the isolate. These data are in the same trend with those obtained by Lin *et al.* (1974). They reported that, all sunflower protein products bound more oil than the soy products and in this regard, structurally, the sunflower proteins could be more lipophilic than the soy proteins. Aruna Venktesh and Prakash (1993) reported OAC values of 286% for sunflower DF and 130% for acidic butanol treated DF (the flour was washed 7 times with acidic butanol at pH 5.8) and

they attributed this decrease in OAC of the treated flour to the aggregation of the protein, which reduces the number of nonpolar residues that are exposed.

The emulsification capacity (EC): The results are expressed as ml oil emulsified by 100 ml of 2% (w/v) sample suspension and presented in Table 5. These results showed that, soybean DF had the lowest EC value (120) compared to sunflower untreated DF (242), treated DF (228), PC (248) and PIs (257). Treated DF exhibited lower EC than the untreated DF, but remained much higher than the corresponding value for soybean DF. These results are in agreement with those of Lusas (1985) who reported that sunflower seed DF, PC and PIs exhibit higher OAC and emulsifying properties and lower WAC than soy products.

Foaming capacity (FC): It was expressed as % volume increase and also presented in Table 5. All samples had FC values higher than soybean DF and the increase of these values was in the direction of the increase in protein content. The studied samples had the following FC values: soybean DF (78), sunflower untreated DF (212), treated DF (236), PC (254) and PIs (263). The acidic ethanol-treated DF had a higher FC value than that of untreated one, this could be due to the improved solubility (at pH 7.0) of the treated flour (52%) as compared to the untreated one (38%).

Foam stability (FS): as % foam volume of the initial volume of foam versus time is shown in Fig. 2. Both treated and untreated sunflower DF possessed higher FS values than soybean DF at all studied period of 120 min, whereas the treated sunflower DF was equal or slightly better than the untreated one regarding the stability of foam up to first 25 min then started to decrease in a higher rate. On the other hand, the falling rate of foam volume was fast in the initial 15 min for PC, the initial 8 min for PI_S after which, it was slower up to 30 min for PC, up to 20 min for PI_S then reached plateau.

The obtained results indicated that sunflower DF treated with acidic ethanol had higher FC and FS compared to soybean DF and such treatment enhanced its FC, while there was only a marginal

decrease in its FS. Moreover, the PC and PI_S prepared from this treated flour showed also good foam ability.

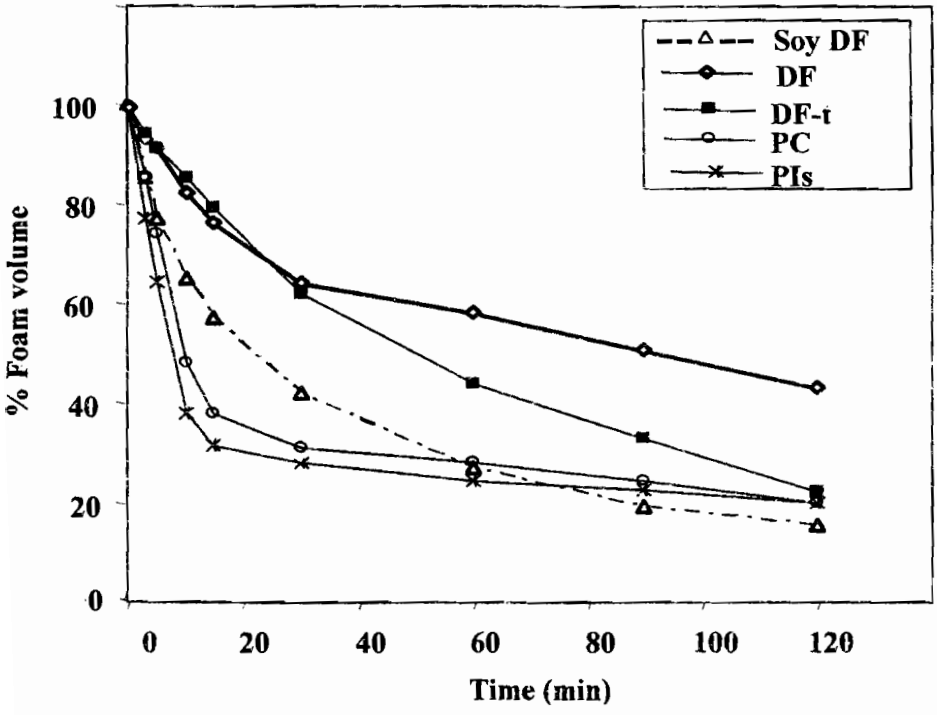

Fig. 2: Foam stability versus time curves for the defatted flour "untreated (DF) and treated (DF-t) with acidic ethanol", protein concentrate (PC) and protein isolate (PI_S) of sunflower seed and soybean DF (as a reference).

Lin *et al.* (1974) reported that both sunflower DF and PC increased in volume by about 230% compared to 70% for the soy DF and 170% for soy PC. Sosulski and Fleming (1977) found that sunflower products showed better whippability and foam stability than their soybean counter parts while, Kabirullah and Wills (1988) reported that, foaming properties of sunflower protein isolate were similar to that of soy protein isolate. On the other hand, Lin *et al.* (1974) and Canella, (1978) reported that, protein concentrates and

isolated of sunflower had foaming properties that approach those of fresh egg white and sunflower proteins had excellent foam stability.

Gelation, expressed as least gelation concentration (LGC) is shown in Table 5. All studied flour samples (soybean DF, sunflower untreated and treated DF) formed a strong gel at LGC of 10% compared to 12% for PC and 14% for PI_S of sunflower seed. Sosulski (1979) reported that, proteins of sunflower thicken and gel when heated, indicating the potential usefulness in custard-type puddings, sauces and sausage emulsion.

The results of this study indicated that sunflower DF treated with acidic ethanol had good functional properties and could be used to prepare white color protein isolate using the traditional alkali extraction-acid precipitation procedure. This flour had an oil absorption capacity, oil emulsification capacity and foaming properties better than those of soybean DF in addition to similar gelation properties. On the other hand, protein concentrate and isolate prepared from sunflower treated DF also exhibited good functional properties in terms of WAC, OAC, emulsification and foaming as well as gelation properties.

Considering the good functional properties, high protein content and excellent amino acid composition, sunflower DF as well as the PC and PI_S may be successfully used in many food formulations as sources of protein and as good functional ingredients.

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التركيب واللون والخصائص الوظيفية للمكونات البروتينية المحضرة من دقيق بذور عباد الشمس المنزوع الدهن بعد معاملته بالإيثانول الحامضي

مجدي محمود زغلول

قسم علوم الأغذية ــ كلية الزراعة ــ جامعة المنيا

تم تحضير دقيق بذور عباد الشمس المنزوع الدهن ذو حجم حبيبات ٨٠ مش بعد استخلاص الزيت بواسطة الهكسان من البذور المقشورة يدوياً والمطحونة طحناً خشناً ثم تمت معاملته بالإيثانول الحامضى بغرض إزالة حمض الكلوروجينك. تم تقييم تأثير هذه المعاملة على تركيب الأحماض الأمينية، التركيب الكيماوي، اللون والخصائص الوظيفية للدقيق ومركز ومعزول البروتينات المحضرة من هذا الدقيق المعامل مع استخدام دقيق فول الصويا المنزوع الدهن كمرجع للمقارنة. أظهرت النتائج احتواء لب بذور عباد الشمس على ٥٤,٤١% زيت، ٢٧,٧٣% بروتين، ٣,٩٩% رماد، ٣,٣٦% ألياف، ١٠,٥٠% كربوهيدرات (على أساس وزن جاف) وأدى استخلاص الزيت إلى زيادة في كل المكونات الأخرى في الدقيق المنزوع الدهن المتحصل عليه وخاصة فى محتوى البروتين. لم يوجد اختلاف ملحوظ في محتوى الأحماض الأمينية الأساسية في كل من دقيق عباد الشمس المعامل والغير معامل وكان الليسين بمثابة الحمض الأميني المحدد الأول في كل منهما بينما كانت الأحماض الأمينية الكبريتية هي المحدد الأول في حالة دقيق الصويا المنزوع الدهن.

المحضر من دقيق عباد الشمس الغير معامل بدى غامقاً للعين المجردة وكان التغير فى لونه واضحاً (لذا استبعد فى دراسة الخصائص الوظيفية) بينما بدت كل العينات الأخرى فاتحة اللون مبيضة ومشابهة لبعضها البعض وتقدير اللون أيد ذلك. كانت بروتينات دقيق عباد الشمس (المعامل والغير معامل) أقل قابلية للذوبان بصورة واضحة على الجانب الحامضى لرقم الحموضة (pH) مقارنة ببروتينات دقيق الصويا بينما على الجانب القلوي وبخاصة عند رقم حموضة = 9 أو أعلى كانت بروتينات الثلاثة أنواع من الدقيق ذات ذائبية عالية. بالمقارنة مع دقيق عباد الشمس (المعامل والغير معامل) فإن منحنى الذائبية لمركز البروتين كان له مدى أقل ذائبية حاد إلى حد ما حول رقم حموضة = 5. بينما مركز البروتين كان مدى أقل ذائبية له أكثر حدة وأخذ الشكل U مماثلاً في ذلك منحنى ذائبية دقيق الصويا.

الخصائص الوظيفية لدقيق عباد الشمس المعامل بالإيثانول الحامضى كانت جيدة فهذا الدقيق كانت له مقدرة على امتصاص الزيت، استحلاب الدهن وتكوين الرغوة أفضل من دقيق الصويا بالإضافة إلى خصائص تكوين جيلي مشابهة لدقيق الصويا. ومن ناحية أخرى فإن مركز ومعزول البروتين المحضر من هذا الدقيق أظهرت أيضاً خصائص وظيفية جيدة فيما يتعلق بالقدرة على امتصاص الماء، امتصاص الدهن واستحلاب الزيت وتكوين الرغوة وكذلك تكوين الجيلى.

مع الأخذ في الاعتبار الخصائص الوظيفية الجيدة والمحتوى المرتفع للبروتين وتركيب الأحماض الأمينية الممتاز بالإضافة إلى إمكانية تحضير معزول بروتين ذو لون أبيض مقبول -- فإن دقيق عباد الشمس المنزوع الدهن والمعامل بالإيثانول الحامضى وكذلك مركز ومعزول البروتين ربما يمكن أن تستخدم بنجاح في العديد من الأغذية كمصدر للبروتين وكمكونات وظيفية.