T1988TECH01

PROCESSING OF SUNFLOWER SEED FOR VALUE ADDED PRODUCTS - NEWER CONCEPTS

M.C. Shamanthaka Sastry and N. Subramanian
Oilseed Technology
Central Food Technological Research Institute
Mysore-570 013, India

SUMMARY

Sunflower cultivation in India, though of recent origin is making rapid progress, the present production being 500,000 t/annum. The seed is crushed for oil in expellers and the resultant cake is used for cattlefeed in admixture with other oilseed cakes. Because of the high fibre (22%) and low protein (28%), it fetches low price in the market. An integrated process has been developed to obtain superior quality oil and meal. The process involves pre-cleaning, grading and dehulling of the seeds at the optimum moisture level prior to oil extraction. The meal obtained from the dehulled material is low in fibre (5%) and high in protein content (44%). The dehulled seed yields an oil with low FFA (1%) and wax content (0.1%). However, the presence of polyphenolic compounds (2.83%) and phytin (3.9%) in the meal impart dark colour to the product and lowers the nutritive quality.

Different approaches for the improvement of the nutritional quality of the seed and meal have been tried. These are (1) Acidic-NaCl treatment to kernels; (2) Dry heating of kernels under optimum conditions; (3) Washing of kernels at pH 7-7.5 with H_2O; (4) Autoclaving of defatted meal; (5) Acid washing of defatted meal at pH 3-3.5. The resultant defatted meals were evaluated by both chemical and biological procedures. Acidic-NaCl treated kernels and Acid washed meals were found to be superior by both in their composition and nutritional aspects. Supplementation of the meal with 0.2% L-Lysine HCl corrects the lysine deficiency and improves its nutritive value.

The functional properties of the protein rich meal have been improved both by dehulling and removal of polyphenols. Polyphenol free concentrates have superior water and fat absorption, oil emulsification and whipping properties. The value added products prepared from it such as salted and spiced snacks, sunflower butter, bakery products, meat patties and milk beverages have been evaluated and found acceptable.

INTRODUCTION

The edible oil economy in India leans very much on groundnut, its annual production being 5 million tonnes. Sunflower cultivation started in the mid 70's has made significant progress as a potential oilseed crop under dry land agriculture of the country. The current estimated annual production of sunflower seed is nearly 500,000 tonnes grown in 800,000 hectares. Varieties such as EC-68413,414, 415, Sunrise and Morden obtained initially from USSR and Canada, have been found to suit the agroclimatic conditions and different cropping systems in India. Sunflower oil, is commercially produced and marketed and the current availability is about 54,000 tonnes per year.

Present status of sunflower processing in India

Sunflower seed contains 25% of hull fraction (Bernardini, 1985). Whole sunflower seeds with the hull are crushed in small screw presses which are in large number in the country. Seeds with varied proportions of moisture and extraneous matter is brought in small quantities from the farms to the market. The oil miller purchases the seeds and stores it for varying periods before crushing. Such poor quality seeds having immature, infested and unfilled seeds yield an oil

with high wax and FFA content. Low recovery of oil and poor unhygienic quality of cake are the common features in most oil mills.

Crushing of undehulled seeds yields a cake having high residual oil content of nearly 12-14% and the cake deteriorates during storage. Further, the cake has a high fibre content (22%) which makes it unsuitable for poultry feeds.

There are only 3 large units with a capacity of 40-60 tonnes/day having the facilities for decortication, expeller pressing and solvent extraction. The seed is dehulled using bar dehullers, the extent of dehulling being 5-7%. Some hulls are used as fuel for the boiler and the rest is ground and added back to the kernels before expelling; the expeller cake is solvent extracted and the deoiled meal used in compounded feeds.

The presence of hulls in sunflower during oil expelling and extraction has another consequence. The waxy coating of the hull surface enters the oil and imparts a haziness to it (Bernardini, 1985). Alkali refining at a low temperature removes this wax, but the oil losses and cost of refining are high. Moreover, for reasons of flavour, people mostly buy and use unrefined oils. This is specially true in the case of screw pressed oils of sesame, groundnut, mustard, nigerseed, safflower, etc.

The use of hygienically prepared oil cake from groundnut and soybean for human foods has received considerable research attention in India (Subramanyam et al, 1957). However, the total use of such flours in the country at present is estimated to be in the order of only 20,000 tonnes annually. Edible soya and groundnut flours are currently used in the preparation of cooked and extruded foods, flavoured beverages and in the nutritionally balanced food supplements for mass feeding programmes.

The preparation of edible flours from sunflower seed has been hampered by the presence of hulls and polyphenols of which chlorogenic acid (CGA) constitutes 70% of the total. These phenolic compounds cause discoloration in food systems specially during alkaline extraction of the protein (Pomenta and Burns, 1971). Various methods have been reported in literature for removal of polyphenols from sunflower seed involving the use of aqueous or organic solvents (Sastry, 1978).

Eklund (1975) reported that phytate phosphorus constitutes 8.8 mg/g in sunflower protein concentrate. 50% of the total phosphorus present in it was bound as phytin (the calcium magnesium salt of phytic acid) in protein concentrate.

Objectives

In this investigation, the following studies have been made.

(1) A simple method of removing hull fraction to get kernels and further processing to yield good quality oil and cake for direct use in foods;

(2) The extraction of polyphenols from sunflower kernels/flour by using various aqueous solvents as a function of pH, temperature and salt concentrations have been carried out. Technological processes such as roasting, autoclaving and expeller pressing have also been included. The protein concentrates obtained can preferably be utilised in value added products;

(3) The effect of above processes on the physico-chemical and nutritional quality of proteins; and

(4) In a model system, isolated polyphenol free 11S protein from sunflower is interacted with CGA, CA and QA as a function of pH, temp. and salt concn. The results obtained were used to substantiate the validity of the data on the above processes.

MATERIALS

Black hybrid variety (EC-68414) sunflower seeds were obtained from the Agro-Seed Corporation, Mysore. Chlorogenic acid (CGA), Caffeic acid (CA), Quinic acid (QA), and 1,2-fluoro dinitrobenzene (FDNB) were from Sigma Chemical Co,USA.

METHODS

Dehulling: Sunflower seeds were cleaned and graded using BSS3 and BSS5 screens to separate small, medium and large seeds. The graded seeds were dehulled by centrifugal sheller followed by air classification (Sastry, 1978). This sheller consists of a circular metal housing lined with hard rubber and having an inlet at the centre for feeding sunflower seed. The material falls on an impeller, which directs the seed in a curved path against the rubber lining of the sheller by centrifugal force. As a result of the impact the seed gets dehulled.

Removal of polyphenols: (a) Aqueous extractions: The dehulled seeds were pressed in a laboratory carver press at 5000-6000 psi for 2 hr. and nearly 30% of the total oil recovered. The kernels were brushed on a wire mesh screen (30 BSS) and the translucent layer is removed by air classification. Removal of polyphenols from partially defatted kernels with acidulated water at different pH were carried out by the following procedures.

i) NaCl solutions 2% and 1% (W/V) were used for first and second extractions, keeping the kernel to solvent ratios to 1:12 and 1:5 respectively. The time of extractions were 60 and 20 min. Protein losses were minimised by adjusting the pH to 5.5. Water wash was given at the end by stirring for 10 min (SPC-1).

ii) Water was used as an extractant for comparison (SPC-2).

iii) Partially defatted kernels were extracted in acidulated water only, in a similar pattern as (i) at pH 3.5 (SPC-3).

iv) Broken kernels without partial defatting were extracted 5 times with tap water (1:10) at 70°C for 60 min. each (SPC-4).

All these processed samples were dried at 50°C for 40 min. in a through flow drier, flaked and solvent extracted using hexane. The samples were desolventised and powdered to pass through 60 mesh (BSS) screen.

(b) Heat processing: Heat processing is one of the methods for complete removal/inactivation of toxic principles such as trypsin inhibitors, which influences the nutritional value of food proteins. The objective of the following study was to determine the effect of dry and wet heat treatment of sunflower meal on polyphenols and nutrtional quality of protein.

i) The kernels were salt roasted using NaCl (1:1) in an electrical roaster at 120°C for 5 min. The roasted kernels were sieved to remove sodium chloride, flaked and solvent extracted (SPC-5)

ii) Defatted sunflower meal was autoclaved at 1 kg/cm^2 for periods varying from 5 to 60 min. The autoclaved samples were sundried (SPC-6)

iii) The dehulled kernels were expeller pressed. The cake was solvent extracted (SPC-7)

All the samples were ground to pass through 60 mesh (BSS).

ANALYTICAL METHODS

Proximate composition of all the samples was determined by the AOAC methods (1980). CGA, CA and QA contents of the meal were estimated by the procedure of Pomenta and Burns (1971). Phytin was estimated by Wheeler and Ferrel procedure (1971); Available lysine by Carpenter's procedure (1960); Invitro digestibility of the proteins by the method of Saunders et al (1973). Nitrogen solubility in 0.02N was studied by the procedure of Lyman et al)1953). Nutritional studies to assess protein quality were studied according to Campbell's procedure (1963). The data were analysed for statistical significance using Duncan's new multiple range test. Bulk density of sunflower meals was measured by the method of Wang and Kinsella (1976). Water absorption capacity (WAC) was determined by the modification of the centrifuge technique of Janicki and Walczak (1954) and fat absorption capacity by the method of Sosulski et al (1974).

RESULTS AND DISCUSSION

a) Dehulling

Sunflower seed contains high amount of oil (about 45%) and has also a high proportion of hulls (25%). Commercial expeller cake derived from the undehulled seeds was found to have high fat (14%) and crude fibre (20-22%) while the cake from the dehulled seed retained only lesser amounts of fat (9%) and fibre (8%). Dehulling of sunflower seed prior to oil milling yielded a superior quality oil and protein rich meal (Sastry and Subramanian, 1984).

Some of the unique advantages of dehulling are:

(i) The oil obtained is low in FFA (0.04%) and wax (0.04%). This obviates the time consuming and expensive process of wax removal during refining. This oil does not need refining.

(ii) The cake obtained has a light grey colour and is rich in protein (44%) compared to 28% protein in the cake from undehulled seed; the corresponding values for fibre in the two cakes are 8% and 22%. The dehulled seed cake can be further processed for obtaining edible quality flour by removing of polyphenols.

(iii) By dehulling followed by expeller pressing the residual oil content in the cake is reduced to 9-10%. Consequently the overall oil yield is increased by 3-4%.

(iv) The plant capacity is increased by 40%.

(v) There is reduction of nearly 40% in the power consumption as a result of dehulling.

The dehulled seed had a higher percentage of oil (59.7%) and protein (31.5%) and low crude fibre content (2.9%), as compared to the whole seed having 45% oil, 23% protein and 16% crude fibre content (Table 1). The CGA, CA and QA

contents in dehulled seeds were 0.72%, 0.30% and 0.16% respectively. Defatted sunflower meal from the dehulled seed contained about 54% protein and 9% crude fibre. Sunflower proteins are primarily deficient in lysine. The available lysine content was found to be 3.12 g/16gN (Table 2). The nutritional value of sunflower meal proteins was significantly improved after dehulling the seed. The protein efficiency ratio (PER) values of the proteins in the undehulled and dehulled flours were 1.74 and 1.98 respectively. Fortification of the dehulled sunflower meal with lysine at a level of 0.2 g l-lysine HCl/100g of flour was found to correct the limiting amino acid deficiency and the PER value was increased to 2.40.

b) Extraction of polyphenols

Extraction of the phenolic compounds from partially defatted kernels using aqueous solvents at optimum pH and NaCl concentration offers some advantages such as (a) easy mixing and separation of the liquid-solid system; (b) minimisation of protein loss. Almost complete extraction of polyphenols was accomplished in the meal under optimal conditions and CGA was not detectable. However, the use of NaCl leads to slightly higher losses of protein content (7.7%) and solubles (28%) from the meal than in water extraction (2.4% and 14%) at pH 6.8. The protein content of the concentrate (SPC-1) was increased from 53.3% to 59.7% and the phytin content reduced from 3.9% to 2.3%. (Table 1). It also gave a higher value of 3.4 g/16gN for available lysine compared to 3.1g in the case of the defatted meal; SPC-1 had superior nutritional quality with an *in vitro* protein digestibility of 96%, PER of 2.4 and NPU of 64; the corresponding values for the defatted meal were 81%, 1.98 and 65 respectively (Table 2). However, the water extracted meal (SPC-2) had 0.99% of total polyphenols compared to 2.46% of defatted flour showing the removal of only 60% during extraction.

Taha and Nackrashy (1981) have reported that the relationship between phytate solubility and protein solubility of sunflower meal is influenced by pH. Based on the solubility differences between these two, it was reported that with four successive extractions at pH 4.5, 99% of phytate and 65% CGA were removed from the meal. This resulted in the loss of proteins to the extent of 23%. In the present work two successive extractions at pH 3.5 removed 50% of phytic acid and the loss of protein was less than 4.5%. CGA was also partially extracted to the extent of 44%. Such low solubility of CGA at pH 3.5 is due to the fact that the interaction of sunflower proteins with CGA, CA, and QA increases at low pH range of 2-4 (Sastry, 1985). The protein content in acid extracted flour (SPC-3) was increased to 59.8% (Table 1). However, the nutritional quality of SPC-3 was not much altered compared to defatted flour due to the acid treatment.

The extractability of CGA in water at pH 6.8 was determined in the temperature range of 5 to 80°C. Extractability increased in the temperature range of 5 to 50°C from 55% to 68%. However, between 50-80°C there was no further increase. Sosulski *et al* (1972) have reported that the extraction of CGA was higher at 80°C than at 60°C. The protein content of the meal (SPC-4) was more or less constant upto 65°C and a slight increase was observed above this temperature. Possibly the protein was denatured at higher temperature and its solubility in water was reduced (Protein loss: 2.2%).

Roasting and expeller pressing processes strongly reduce the solubility of proteins hindering the removal of polyphenols and carbohydrates (Sastry, 1978). Milic *et al* (1968) observed a decrease in CGA followed by an increase of CA and QA on heat treatment of sunflower meal. However, in the present study, the results have shown the decrease of these acids, when the meal was subjected

to roasting and autoclaving. It is possible that these phenolic acids are destroyed to some extent by oxidation in the presence of heat. Both the roasted (SPC-5) and autoclaved (SPC-6) samples showed progressive decrease of nitrogen solubility with prolonged heat treatment. Any possible advantage in decreasing the levels of CGA, CA and QA contents by moderate heat treatment of meal was apparently lost due to loss of its available lysine content, lowering PER from 1.98 to 1.74 and NPU from 65 to 56 respectively. Roasting of kernels (SPC-6) had beneficial effect on *in vitro* digestibility. Milic *et al* (1968) found inhibition of trypsin activity and lipase activity by polyphenols.

c) Functional properties

Sunflower proteins have desirable functional properties, which could expand their use in food products. The values of WAC, FAC and BD are given in Table 3. The values of WAC, FAC have been given on both meal and protein basis. The defatted sunflower meal had WAC value of 255g/100g of meal which was similar reported value by Rahma and Narasinga Rao (1981). The higher WAC (485-680) of the extracted meals could be due to the denaturation of proteins thereby exposing a greater number of water binding sites or removal of non-protein constituents during extraction. Fleming *et al* (1974) observed that addition of NaCl at 5% level increased the WAC from 128 to 275. It is possible that the higher WAC of the concentrate could be due to NaCl contamination in the meal itself. The FAC value of 210 for defatted flour agrees with the value of Rahma and Narasinga Rao (1981). All sunflower concentrates showed higher FAC values (415-520). Structurally the sunflower products could be more lipophilic.

MODEL STUDIES

Binding of polyphenols with 11S proteins

11S forms the major protein fraction in sunflower. A method has been devised to isolate 11S protein free from polyphenols. Using model system we have studied the binding of CGA, CA and QA by the 11S protein as a function of pH, temperature and solvent composition. The results obtained substantiate the validity of aqueous and salt extractions at various pH and temperatures carried out in the present investigation.

The results have shown that the binding of CGA, CA and QA by the protein decreases with increase in pH of measurement. The binding follows in order of pH 4.0 > pH 5.5 > pH 7.0 and the association constant has higher value at pH 4.0. These polyphenols bind to 11S with positive cooperativity. Effect of pH indicated that the maximum binding occurred at pH 4.0. Decrease in pH increased No.of binding sites. Addition of NaCl decreases the binding. Higher the salt concentration, greater the decrease. The effect of salt is not a direct one but it is a indirect one. The binding of CGA, CA and QA by the protein increases when it is dissociated. NaCl prevented the dissociation of protein and thereby reduced the binding.

We have reported that the binding of CGA, CA and QA by the 11S protein is highly temperature dependent. Binding at 45°C was much lower than at 30°C. At 55°C the protein did not bind CGA and CA at all. These results suggest that at higher temperature, CGA, CA and QA exist in the unbound form and can be extracted easily in water. This also explains why above 55°C, extractibility does not increase. The results also have shown that the extent of hydrolysis of 11S protein by trypsin and α-chymotrypsin and pepsin is affected by the addition of CGA. In conclusion, the binding of CGA and CA by 11S protein did not involve any ionic linkages and possibly only hydrogen bonding was involved.

Binding of 11S protein follows the order CGA > CA > QA. Possibly the chain length of the molecule determines the affinity of the protein for the polyphenols.

VALUE ADDED PRODUCTS

Roasted kernels were utilised in the preparation of snacks, sunflower butter and bakery products. Concentrates such as SPC-1 and SPC-3 were used in the preparation of milk beverages and meat patties. These products were found acceptable.

REFERENCES

A.O.A.C. (1980), Methods of Analysis, Washington,D.C.

Bernardini,E (1985), "Oilseeds, oils and fats", (Ed) B.E. Oil Publishing House, Roma

Campbell,J.A. (1963), "Evaluation of protein quality", Pub. 100, NAC-NRC, Washington,D.C.

Carpenter,K.J. (1960), Biochem.J., 77, 604

Eklund,A (1975), Upsala J. Med.Sci., 80, 5

Fleming,S.E., Sosulski,F.M., Kilara,A and Humbert,E.S. (1974), J.Food Sci, 39, 188

Janicki,N.A. and Walczak,J (1954), Adv. Food Res., 10, 355

Lyman,C.M., Chang,W.Y., and Couch,J.R. (1953), J. Nutr., 49, 679

Milic,B, Stojonovic,S., Vucurevic,N. and Turcic,M. (1978), J.Sci.Food and Agri. 19, 108

Pomenta,J.V., and Burns,E.E. (1971), J. Food Sci, 36, 490

Sastry,M.C.S, (1978), M.Sc. Thesis "Studies on Sunflower seed protein", University of Mysore, Mysore, India

Sastry,M.C.S. and Subramanian,N. (1984), JAOCS, 61(6), 1039

Sastry,M.C.S. and Subramanian,N. (1985), JAOCS, 62(7), 1131

Sastry,M.C.S. (1985), Ph.D. Thesis "Interaction of sunflower proteins", Univ. of Mysore, Mysore, India

Saunders,R.M., Connor,M.A., Booth,A.V., Bickoff,E.M., and Kohler,G.O. (1973), J. Nutr., 103, 530

Sosulski,F.W., Humbert,E.S., Bui,K. and Jones,J.D. (1976), J. Food Sci, 41, 1348

Sosulski,F.W., Mccleary,C.W. and Soliman,F.S. (1973), J. Food Sci, 37, 253

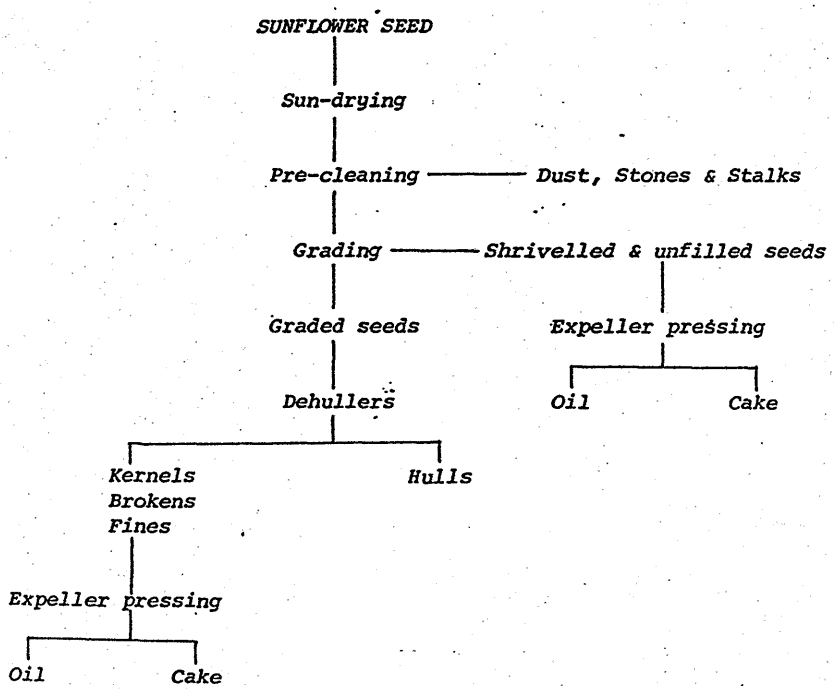
Subramanyam,V, Rama Rao,G., Kuppuswamy,S., Narayana Rao,M., and Swaminathan,M. (1957), Food Sci, 6, 76

Taha and Nackrashy,A.S.E.L. (1981), Die Nahrung, 25, 473

Wang,J.C, and Kinsella,J.E. (1976), J. Food Sci, 41, 286

Wheeler,E.L. and Ferrel,R.E. (1971), Cereal Chem. 48, 313

Rahma,E.H., and Narasinga Rao,M.S., (1979), J.Food Sci., 44, 579



Flow sheet for processing of sunflower seed

Table 1: Physico-chemical characteristics of sunflower seed and processed flours

Samples	Protein %	Crude fibre %	Ash %	Phytin %	Polyphenols, %			
					CGA	CA	QA	Total
SPC-1	59.7	2.1	3.4	2.33	N.D	0.04	Nil	0.04
SPC-2	57.3	2.3	3.2	2.80	0.74	0.20	0.05	0.99
SPC-3	59.8	3.2	3.6	1.95	0.78	0.06	Nil	0.84
SPC-4	54.8	3.8	3.8	2.43	0.28	0.26	Nil	0.54
SPC-5	56.0	5.8	4.2	3.00	0.29	0.34	0.21	0.84
SPC-6								
15 min	58.0	8.9	5.1	3.00	0.75	0.67	0.31	1.73
30 min					0.50	0.53	0.31	1.34
60 min					0.20	0.40	0.20	0.80
SPC-7	54.3	8.4	5.0	2.74	0.62	0.62	0.40	1.64
Defatted flour	53.3	8.9	5.8	3.93	1.41	0.72	0.33	2.46
Dehulled kernel	31.5	2.9	3.2	-	0.72	0.30	0.16	1.18
Whole seed	23.0	16.0	2.7	-	0.47	0.37	0.21	1.05
Hull	5.9	50.0	3.1	-	0.21	0.08	0.08	0.37

N.D. = Not detectable

Table 2: Nutritional characteristics of processed samples and nitrogen solubility

	Available lysine (g/16g.N)	In vitro digesti-bility,%	PER	NPU	N solubility in 0.02N NaOH %
SPC-1	3.40	96	2.39	64	87
SPC-2	3.00	90			87
SPC-3	2.15	94	1.92	58	85
SPC-4	2.80	84			75
SPC-5	2.15	92			68
SPC-6					
15 min	2.83	89	1.74	56	45
30 min	2.52	85			33
60 min	2.08	82			6
SPC-7	2.82	85			65
Defatted flour	3.12	81	1.98	65	93
Defatted flour + 0.2% lysine HCl			2.40	71	

Table 3: Some functional properties of selected processed flours

Meal	WAC (%)		FAC (%)		Bulk Density g/ml
	Meal	Protein	Meal	Protein	
Defatted flour	255	502	210	413	0.232
SPC-1	680	1292	520	988	0.196
SPC-3	485	912	415	780	0.169
SPC-4	510	931	440	803	0.175