Technical News Feature

Pilot Plant Production of Sunflower Seed Flour

S.P. CLARK, P.J. WAN, S.W. MATLOCK, Food Protein Research and Development Center, Texas A&M University, College Station, TX 77843

ABSTRACT

Hull-free kernels from confectionary-type sunflower seed were prepressed with two levels of heat treatment and two levels of severity of pressing. Cakes were solvent extracted, desolventized in a continuous, pilot size extractor, and ground into flour. For comparison, kernels were also pressed into flour using direct solvent extraction and desolventizing at room temperature. Qualities of oil and of flour from different treatments were compared. Oils were all of good quality with no differences among treatments. Flours showed no distinct differences in dispersible nitrogen at pH values between 2 and 12, indicating that processing conditions did not damage the solubility of the protein. All cake and flour samples were high in residual hexane, showing the need for a deodorizer in the pilot plant. Treatments did not affect particle size distribution in flours. The flour samples all fell within the range for satisfactory microbiological quality, although bacteria count increased considerably during grinding of cake into flour. Treatments affected dry color but not wetted color of flour, with the more intense heating and pressing producing slightly darker flours. Amino acid compositions were not affected by process treatments.

INTRODUCTION

Research conducted under a contract has shown that direct solvent extraction of hull-free kernels is difficult and probably impractical with ordinary flake preparation procedures followed by percolation-type solvent extraction. This agrees with industrial practice for which no direct solvent extraction plants are known to be operating on hull-free kernels. One plant was reported to use the filtration-extraction process on kernels which still contained ca. 10% hulls. Residual oil in meal was 1.6% (1). Another direct extraction process employed double extractions with desolventizing and flaking between extractions. The seed was hulled, but no information was given on purity of kernels or type of seed. Residual oil in meal was 0.4% (2).

Direct solvent extraction of cracked, flaked, undecorticated seed, followed by separation of proteinaceous solids and hulls was conducted in pilot plant runs (a paper describing this is in preparation). The work demonstrated that low fiber meal containing ca. 10% crude fiber could be produced. However, the meal was much too dark for human food even if it were low enough in crude fiber, which was doubtful. The dark color was caused largely by small particles of the exterior surface of the hull, which were detached during processing and could not be removed from the meal by screening. In other work under the contract, residual hulls in flour started showing as black discoloration at levels of ca. 1% hulls (equivalent to ca. 3% unhulled seed in kernels).

Numerous investigations have reported on heat treatment of oilseeds or oilseed products to decrease the dispersibility of protein in water or in salt solutions. This has been reported for laboratory as well as plant investigations of soybeans, peanuts and cottonseed (3-8). Mild pressing, such as for prepress solvent operations, was relatively less damaging than cooking or desolventizing for cottonseed or safflower (9,10).

The findings described above indicated that hull-free kernels, processed by prepress solvent extraction, would be the essentials of a process to make food grade flour from sunflower seed. This is an account of pilot plant trials on such a process.

MATERIALS AND METHODS

Proximate analyses on raw materials and products, and evaluation of oil quality, were performed in accordance with methods of the American Oil Chemists' Society (11). Oil-refining loss on screw-pressed oil was determined by method Ca 9a-52 with the cottonseed expeller modification. Oil colors were measured by method Cc 13b-45 with Lovibond Titometer.

Dispersible nitrogen profiles were performed by shaking extractions of flour or meal in distilled water at 37 C for 30 min at different pH levels, as described by Lawhon et al. (12). This method measured the nitrogenous materials extracted under the conditions of the test. The pH values shown (Figure 1) were those at the end of the extraction period and after centrifuging.

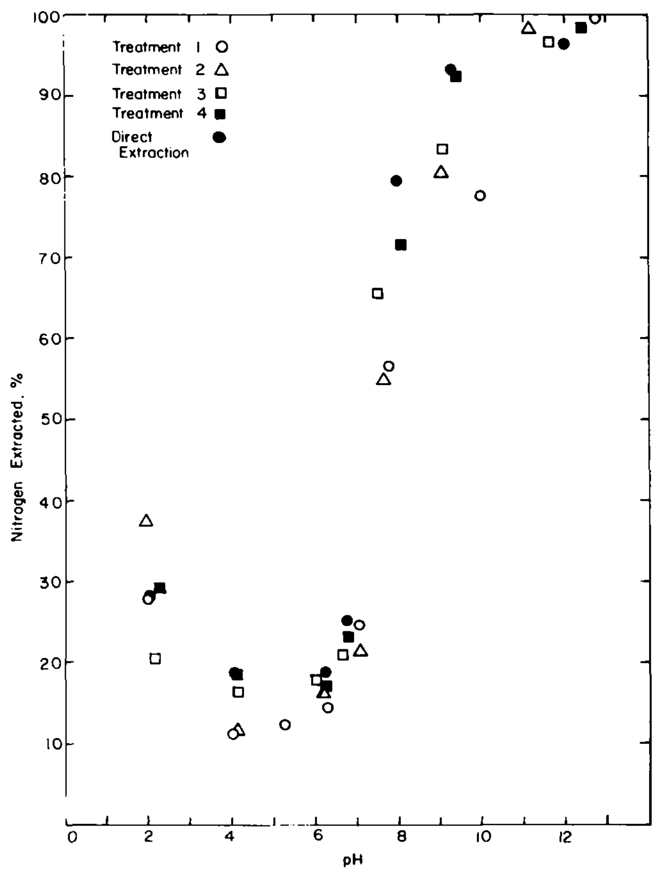

FIG. 1. Dispersible nitrogen profiles for flours made from prepress solvent-extracted cake and direct solvent-extracted meal.

Residual hexane determinations in meals were performed according to a method described by Wan et al. (13). Particle size analyses on flour were made with an Alpine Air Jet Sieve. Flour colors were measured with a Hunter Lab Color Difference Meter, Model D25D2. Microbiological assays were performed by recognized methods for food analysis (14).

The flowsheet below shows processing steps which were followed.

HULL-FREE KERNELS
↓
Condition
↓
Press ——————→ **OIL**
↓
Solvent extract ——————→ **OIL**
↓
Desolventize solids
↓
Grind
↓
FLOUR

Hull-free kernels were procured from Dahlgren & Company, Crookston, MN. They were from confectionary seed of mixed varieties designated D518, D611 and D613. They had been screened and contained no hulls or small broken particles.

Conditioning equipment were a 22-in. diameter batch cooker with bottom scraper and steam-jacketed bottom and walls, and an eight-ft.-long, horizontal, steam-jacketed paddle conveyor. The pitch of the paddles in the conveyor was set to deliver ca. 300 pounds per hour at 6.5 rpm and a retention time of ca. 5 min. Feed rate to the press was maintained constant by using a vibratory feeder feeding into the heated conveyor.

Kernels discharging from the conveyor dropped directly into the feed-screw section of a small "Ozawa" screw press. This model S-95 press was manufactured by Cho Giken Kogyo Company, Ltd., Chuoku, Japan. It has a cage 3.9 in. in diameter by 21 5/8 in. long, made from machined rings instead of longitudinal bars as in most screw presses. The rings have machined ridges or grooves that leave spaces through which oil exits from the cage. Oil coming from the cage flowed into a sump from which some of the oil was pumped through a steam-jacketed heat exchanger and then over the cage. The temperature of the recirculated oil was maintained at 85 C (185 F). This heated the cage for start up and then cooled it when caking started and frictional heat raised cage temperatures. Oil equivalent to incoming flow was pumped by the same pump to a storage drum. Oil from a previous run was used to start the press operation on the next run. Thus, oil was not completely separated by batches. Samples of oil for refining loss were taken at the end of a run when oil from the previous run had been lost by dilution. Back pressure on cake issuing from the press was provided by a cone which was movable along the shaft to produce more or less restriction to the discharge of cake. The position of the cone affected the thickness of the cake as well as the residual oil in the cake. The shaft was driven through a variable speed drive at 24 rpm for all trials. Feed rate to the press was 300 to 400 pounds of sunflower kernels per hour. Feed was varied by the feeder to suit the demand of the press.

Combinations of operating parameters for four treatments were set up as shown in Table I. Combinations were two different degrees of preheating, designated A and B, followed by hard or light pressing. Preheat A was heating in the 22-in. cooker for ca. 20 min to a temperature of 82 C (180 F). Preheat B was heating in the steam-jacketed screw conveyor for ca. 5 min. to the temperatures shown in Table I. Light preheating was B alone; greater heating was A plus B.

Hard pressing involved setting the press discharge cone to obtain maximum achievable reduction of oil in kernels. Light pressing involved opening the discharge cone as much as possible while still getting a cake which was dense enough not to crumble when contacted with solvent in the extractor.

Press cake was broken manually and fed into the continuous solvent extractor. The extractor, made by Crown

TABLE I

Processing Conditions for Conditioning and Pressing Kernels and Solvent Extracting Cake

	Treatment number			
	1	2	3	4
Preheating treatment	A + B	B	A + B	B
Time of heating in A, min[a]	20	—	20	—
Temperature reached in A, C	82	—	82	—
Time of heating in B, min[b]	5	5	5	5
Temperature reached in B, C	82-91	71-77	82-91	71-77
Moisture in material to press, %	4.9	4.3	5.2	4.6
Pressing treatment	Hard	Hard	Light	Light
Temperature of circulating oil, C	85	85	85	85
Feed rate to press, lb/hr	300-400	300-400	300-400	300-400
Average cake thickness, 1/1000 in.	33	17	82	68
Solvent extraction				
Temperature of miscella, C	63	63	63	63
Retention time, hr	1	1	1	1
Temperature of solids leaving desolventizer, C	71-77	71-77	71-77	71-77
Retention time in desolventizer, min	5	5	5	5
Steam pressure on desolventizer, psig	60	60	60	60

[a]Heating in a vertical steam jacketed batch cooker.

[b]Heating in a steam jacketed horizontal paddle conveyor.

Iron Works of Minneapolis, MN, was pilot plant size with an extraction bed 8 in. wide by 5 in. deep. Miscella was circulated by pump through the slowly moving extraction bed. The bed including solvent as well as miscella sections, was ca. 12.5 ft long. Retention time of solids in the extractor could be varied through a variable speed drive. Temperature of miscella was maintained at ca. 63 C (145 F) by circulation through steam-heated exchangers.

Solvent-extracted solids discharged from the extractor into a steam-jacketed, horizontal, screw-conveyor-type desolventizer of 10 in. inside diameter with a 10-ft-long jacket. A slow current of air was pulled through the desolventizer to carry vapor to a chilled water condenser. Desolventized solids discharged at a temperature of ca. 77 C (170 F) into an open-head drum.

Extracted cake was ground into flour with an Alpine Contraplex pin mill, Model A 250 CW, having two rotors instead of rotor and stator. Speeds of the rotors were ca. 11,200 and 5,600 rpm.

RESULTS AND DISCUSSION

Confectionary kernels instead of oilseed kernels were used for this work for two reasons. Oilseed kernels were not available at the time needed, and, more importantly, we had been unable to produce completely hull-free kernels from oilseed-type seed. About 1% hull content was as low as we had been able to go (15). As described in the introduction, this was barely low enough for the color of flour not to be darkened by hulls.

Because of the difficulty of preparing hull-free kernels, confectionary seed may prove to be the seed of choice for food purposes. As further support for this point of view, comparison of four commercial oilseed and three commercial confectionary varieties showed quite similar kernel compositions. The principal differences between the two types of seed lay in proportions and thicknesses of hulls and in the degree of black coloring on surfaces of hulls. Whole confectionary seeds were lower in oil because they had a higher proportion of hull (16).

In Table I are data on preheating and pressing sunflower kernels and solvent-extracting press cake. Preheat treatments A plus B were less severe than oilseeds often receive. For example, cottonseed meats for prepressing are rolled and moistened up to 12-15% moisture content, cooked, and then dried to 4-7% and temperatures of 104-114 C (220-240 F) over a period of 30 to 60 min (17).

The Ozawa screw press had been observed to be able to press oil from materials that were judged on the basis of experience to be unpressable with conventional presses. In other words, the Ozawa press will make a cake, and express oil from material that is not changed enough by heat treatment and drying to allow caking by conventional presses. The rings forming the cage in the Ozawa press encircle the screw. Presumably the joints between rings offer more frictional resistance to flow of solids than do parallel cage bars, and this resistance allows pressure to be built up with materials which otherwise would not cake. In a conventional press the cage is formed by bars that run parallel to the screw and offer less resistance to flow. Pressure is difficult to build up in a conventional press unless the material has been denatured and dried enough to considerably reduce its plasticity. Regulation of temperature by oil flow over the cage was important in that if oil flow stopped, either the cake would cease to flow from the discharge, or the cake consistency would change to soft, unpressed material.

Table II gives information on quantities of products made, and other process data. The no-load amperage on six-240 volt, 3 phase motors associated with the grinding installation was 61 amperes. The load under grinding conditions was 100.5 amp. for batch one, grinding at 22 pound per min. Grinding rates on other batches ranged from 12 to 16 lb/min as shown in Table II.

Table III presents proximate analyses of kernels and products. Cakes from more preheating, treatments 1 and 3, were lower in oil than treatments 2 and 4 with less preheating. Hard pressing was distinguished from light pressing by several percentage points in oil content (treatments 1 and 2 vs. 3 and 4). Likewise, residual oil in solvent-extracted cake and flour was twice as great in lightly pressed material compared with hard pressed material.

Because of variability in analytical values, nitrogen solubility index did not seem to be a good way to evaluate the effects of heat damage during processing, and therefore we performed dispersible nitrogen profiles at different pH levels. The results are shown in Figure 1. The standard was flour from direct solvent extraction of approximately 116

TABLE II

Quantities Processed and Rates for Pressing, Solvent Extraction and Cake Grinding

	Treatment number[a]			
	1	2	3	4
Pressing				
Weight of kernels pressed, lb	950	950	950	950
Weight of cake produced, lb	463	416	519	467
Weight of oil produced, lb	433	428	386	387
Loss, lb	54	106	45	96
Solvent extracting				
Extractor running time, hr	2.0	2.9	1.7	2.1
Weight of solvent extracted cake, lb	329.0	329.0	312.0	330.0
Solvent rate to extractor, gal/min	0.8	0.8	0.8	0.8
Grinding extracted cake				
Weight cake to Contraplex mill, lb	392	329	312	330
Weight flour recovered, lb	368	306	301	315
Grinding time, min[b]	17.5	21	22	27
Feed rate to mill, lb/min	22.4	15.7	14.2	12.2

[a]See Table I for description of treatments.

[b]Speeds of mill rotors were about 11,200 and 5600 rpm.

TABLE III

Proximate Analyses of Kernels and Products from Prepress Solvent Extraction of Sunflower Kernels

Material[a]	Moisture %	Oil %	Nitrogen %	Crude fiber %	Ash %
Kernels before heating:					
Treatment 1	5.4	50.2	4.42	2.8	
2	5.7	46.2	4.44	4.5	
3	5.5	50.3	4.14	5.3	
4	5.4	49.5	4.45	3.3	
Press cake					
Treatment 1	8.3	7.3	8.90	3.7	
2	9.1	8.0	8.55	3.5	
3	8.2	17.6	7.75	3.1	
4	7.0	20.9	7.56	3.1	
Extracted cake					
Treatment 1	5.8	1.2	9.75	3.7	
2	6.3	1.0	9.77	3.9	
3	8.3	2.3	9.40	3.7	
4	6.9	2.1	9.63	3.7	
Flour					
Treatment 1	5.6	1.1	9.89	4.1	6.9
2	5.4	1.3	9.89	3.9	7.4
3	6.8	2.6	9.58	3.9	6.7
4	6.1	2.3	9.78	3.9	6.7
Flour from direct solvent extracted kernels	9.8	1.4	9.33	4.2	6.6

[a]See Table I for description of treatments.

pounds of flaked kernels processed at ambient temperatures. Analyses of this material are also shown in Table III and Figure 1.

The data were insufficient for statistical analysis; however, they did not indicate any distinct differences in quality among the five treatments.

Processing conditions did not affect qualities of prepress oils. Ranges in qualities of oils from the four treatments were: crude oil free fatty acid, 0.4%; refining loss, 4.8 to 5.1%; refined oil colors in terms of Lovibond yellow and red, 35Y, 1.1R to 37Y, 1.2R; bleached oil colors, 10Y, 0.9R to 16Y, 1.0R. Bleaching removed mostly yellow pigments and not red ones. Both refined and bleached oil colors were good, as measured by standards for cottonseed oil.

Residual hexane in solvent-extracted prepress cake ranged from 300 to 900 ppm, showing the need for a deodorizer-stripper following the desolventizer. Values for flour were essentially the same as for cake in every case, showing that grinding did not result in removal of some hexane as might be expected. The allowable levels of hexane in cottonseed flour are 60 ppm (18). A sample of commercial defatted soy flour was found to contain 29 ppm of hexane.

Table IV gives the particle size distribution of flour made by grinding solvent-extracted cake with a pin mill. Processing conditions had no effect on particle sizes.

Table V gives results of bacteriological assays run on flour. Additional assays for E coli, staphlococcus aureus and salmonella were negative for kernels and for all products. Coliforms and fecal coliforms were negative except for flours from treatments 3 and 4 which had counts in these two assays ranging from 9 to 43 per gram of flour.

Bacteriological qualities of kernels and products were all quite good until the flour stage when total count rose considerably. This may have been a result of pulling unfiltered air through the mill cyclone and dust filter, or it may have been caused by our inability to adequately clean the mill between uses. The flour grinding operation will require careful design in a commercial plant to control microbiological contamination. A total aerobic plate count around 10,000 per gram is considered to be good commercial practice, while a count greater than 1,000,000 is hazardous and unacceptable (19). While all the flour samples fell within this range, they all were above good commercial practice.

Color measurement data on flour from the four prepress solvent treatments and from direct solvent extraction of flaked kernels are shown in Table VI. The color difference, ΔE, between the direct solvent-extracted flour as reference and each prepress flour was calculated by the equation $\Delta E=[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$, where ΔL, Δa and Δb are

TABLE IV

Particle Size Distribution of Flour from Solvent-Extracted Prepress Cake[a]

	Treatment number			
Particle size[b]	1 %	2 %	3 %	4 %
<45 µm	54.4	63.8	74.6	86.4
45-75 µm	16.9	20.3	14.1	7.7
75-90 µm	10.5	5.2	2.0	1.1
90-106 µm	5.0	0.0	2.8	1.2
106-125 µm	4.4	3.2	0.0	0.0
125-150 µm	3.1	0.0	3.1	0.0
>150 µm	5.7	7.5	3.4	3.6
Total	100.0	100.0	100.0	100.0

[a]Ground with Alpine Contraplex mill with rotor speeds of 11,200 and 5600 rpm. Particle sizing conducted with Alpine Air Jet Sieve analyzer.

[b]Sizes in microns: 150 µm = 100 mesh U.S. Standard; 43 µm = 325 mesh U.S. Standard.

TABLE V

Bacteriological Assays of Kernels and Products from Processing Sunflower Kernels

Material	Total count[a] (per g)	Yeast/mold (per g)
Kernels		
Treatment 1	5500	300
2	1100	400
3	1100	100
4	2200	100
Press cake		
Treatment 1	5500	<100
2	3100	"
3	400	"
4	1500	"
Extracted cake		
Treatment 1	1300	<100
2	1200	"
3	1000	"
4	800	"
Flour		
Treatment 1	16,000	<100
2	77,000	"
3	330,000	"
4	80,000	"

[a]Aerobic plate count per gram of product.

differences between color readings for reference flour and comparison flour. Most of the color differences were caused by differences in the L factor (lightness). Higher L values indicate greater lightness, or less black.

The dry prepress flours became progressively darker as they were subjected to greater heat during processing. The degree of heat treatment (Table I) increased in order from treatment 4 to treatment 1 and color of flour increased in the same order (increasing ΔE). For wetted flour, all the prepress flours were of about the same degree of darkness, which was greater than wetted direct solvent flour. Even the direct solvent flour was appreciably darker than commercial, high solubility soy flour, compared both dry and wet (no data shown). The darker color of sunflower flour is an attribute that may be associated with natural pigments unique to sunflower seed. Amino acid composition of direct solvent extracted flour was compared with two batches of prepress solvent-extracted flour that had received the most (treatment 1) and the least (treatment 4) amount of heating during processing. No differences were obtained that could be attributed to processing.

ACKNOWLEDGMENT

This work was funded by the USDA and the National Fibers and Food Protein Commission of Texas.

REFERENCES

1. Furman, L.J., E. Amadori M., and O. Guzman F., JAOCS 36:454 (1959).
2. C.M.B., JAOCS 49:364A (1972).
3. Smith, A.K., and S.J. Circle, "Soybeans: Chemistry and Technology," Vol. 1, AVI Publishing Co., Westport, CT, 1972, pp. 302-312.
4. Belter, P.A., and A.K. Smith, JAOCS 29:170 (1952).
5. Ayres, J.L., L.L. Branscombe, and G.M. Rogers, Ibid. 51:133 (1974).
6. Neucere, N.J., R.L. Ory and W.B. Carney, J. Agric. Food Chem. 17:25 (1969).
7. Neucere, N.J., Ibid. 20:252 (1972).
8. Thurber, F.H., H.L.E. Vix, W.A. Pons Jr., A.J. Crovetto and N.B. Knoepfler, JAOCS 31:384 (1954).
9. Pons, Jr., W.A., F.H. Thurber, and C.L. Hoffpauir, Ibid. 32:98 (1955).
10. Betschart, A.A., Ibid. 56:454 (1979).
11. AOCS Official and Tentative Methods, Third Ed., with revisions to 1976.
12. Lawhon, J.T., L.W. Rooney, C.M. Cater, and K.F. Mattil. J. Food Sci. 37:778 (1972).
13. Wan, P.J., M. Chittwood, C.M. Cater, and K.F. Mattil, JAOCS 54(11):542 (1977).
14. United States Department of Health, Education, and Welfare. "Bacteriological Analytical Manual for Foods," Washington, DC, 1973.
15. Clark, S.P., P.J. Wan, and S.W. Matlock, Proc. 8th Int'l. Sunflower Conference, Sunflower Ass'n. of America, Fargo, ND, July 1978.
16. Wan, P.J., G.W. Baker, S.P. Clark, and S.W. Matlock, Cereal Chem. 56(4):352 (1979).
17. Lester, Bill, Oil Mill Gazet. 82(4):8 (1977).
18. United States Code of Federal Regulation, Title 21, Chapter 1, section 172.894, revision of April 1, 1977, page 420.
19. ICMSF. "Microorganisms in Foods," International Commission on Microbiological Specifications for Foods of International Ass'n. of Microbiological Societies. University of Toronto Press, 1972, pp. 54, 113.

[Received March 28, 1979]

TABLE VI

Color Evaluation of Flour From Prepress Solvent and Direct Solvent-Extracted Kernels

Material	Dry flour[a]				Wet flour[a,b]			
	L	a	b	ΔE	L	a	b	ΔE
Direct solvent	82.75	0.65	7.75	0.00	58.85	2.80	11.60	0.00
Prepress solvent								
Treatment 1	76.75	0.55	8.85	6.10	52.75	2.95	11.50	6.10
Treatment 2	79.65	0.30	8.40	3.20	54.70	3.00	11.50	4.20
Treatment 3	80.70	0.70	7.65	2.10	53.80	2.90	11.60	5.10
Treatment 4	81.55	0.40	7.45	1.30	53.40	2.95	10.60	5.50

[a]Readings with Hunter Color Difference Meter. See text for formula used to calculate ΔE.

[b]Flour wetted with water 1:3, w/w.