Effect of Equilibrium Oil Extraction on the Chemical Composition and Sensory Quality of Soy Flour and Concentrates

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Previous studies have shown that ambient-temperature equilibrium, hexane extraction of soy flour yielded the same amount of oil as was extracted from soy flakes by conventional high-temperature processing. The oil obtained at ambient temperatures contained less phospholipid than commercial crude oils obtained by traditional processing. In this study, chemical composition, flavor and odor of soy flour obtained after oil extraction by the equilibrium procedure were evaluated before and after toasting. Results were compared with those obtained for commercial untoasted food-grade soy flakes. Chemical and sensory analyses were performed on soy protein concentrates (SPC) prepared from defatted flour, defatted toasted flour and commercial defatted white food-grade flakes. SPC were made by acid and ethanol-extraction methods. Ethanol extraction of soy flour produced SPC with similar protein, lipid and sensory qualities to those obtained from commercial flakes. Acid extraction produced SPC with more lipid than was obtained by ethanol extraction. Toasted soy flour and flakes had similar sensory properties, as did the SPC prepared from them.

KEY WORDS: Flavor, odor, protein concentrates, sensory, soy flakes, soy flour.

Soy oil is obtained commercially from soy flakes by hexane extraction. Dehulled soybeans are conditioned to 9–10% moisture and passed between smooth flaking rolls to produce flakes, approximately 0.25-mm thick, to aid oil extraction (1). The defatted flakes are treated with super-heated hexane in a flash desolventizer and either ground to flour or processed further to produce soy protein concentrates (SPC). SPC are obtained by removing soluble carbohydrate either by acid extraction (pH 4.5), hot water extraction or washing with 60–80% ethanol to increase the protein content from 40 to 70%.

A low-energy oil extraction procedure has recently been patented in which soy flour is used rather than flakes (2–4). This may be of interest where producing a high-quality oil with low energy costs is important. Flour has not been favored because of extraction and filtration problems with processing equipment. A rapid equilibrium method for measuring total oil in soybeans that involved mixing full-fat soybean flour, instead of flakes, with hexane for 20 min at 20°C was reported by Sheu (2). After this time, an equilibrium was reached with equal concentrations in the miscella and the hexane trapped in the interstices of the meal particles. One percent less oil was obtained with this method than was extracted with the American Oil Chemists' Society's official extraction technique (5). A 1-min equilibrium extraction of 100-mesh flour in hexane extracted 98% of the oil (3). One hour was necessary for complete equilibrium, whereas five hours was needed for the official AOCS extraction method (5). Smaller quantities of phospholipids were extracted by the equilibrium method relative to phospholipids extracted by conventional processing with soy flakes. The reduction in phospholipid content represents a significant increase in oil quality (4). Similarly, favorable results were obtained in a pilot plant study (6). Although this technique produces a superior-quality oil at reduced energy costs relative to current commercial costs, the suitability of the defatted flour for use as a source of protein concentrates has not been examined. This may be of some concern because the residual phospholipid content is probably greater than in flakes after conventional oil extraction.

The objective of this study was to examine the total lipid, phospholipid and protein compositions and sensory quality of defatted flour and concentrates prepared from soybean flour defatted by the equilibrium extraction method. The data obtained from this process were compared with results obtained from commercial soy flakes prepared from the same soybean batch.

MATERIALS AND METHODS

Commercial white desolventized, untoasted, food-grade soy flakes (Central Soya, Gibson City, IL) were obtained for control studies. The nitrogen solubility index of the soy flakes was 63.56 (7). Soy flour was prepared from the same lot of soybeans as the flakes. The soybeans were dried at 75°C in an oven for one hour, cooled and dehulled in a blender. The hulls were removed by aspiration. The remainder was ground in a UDY Cyclone Sample Mill (UDY Corp., Fort Collins, CO) without a screen (3). Full-fat flour was sieved with an Alpine Airjet Sieve (Alpine American Corp., Natick, MA) fitted with a 100-mesh screen.

Defatted soy flour preparation by rapid equilibrium extraction. Soybean oil was extracted as described by Clark and Snyder (3) with the following modifications: A 110-g sample of 100-mesh (<150/μm) flour was extracted by shaking for 5 min in a 1-L Nalgon centrifuge bottle with 440 mL of high-performance liquid chromatography-grade hexane at 20°C. The suspension was centrifuged at 1100 *g*, and the miscella was decanted. The procedure was repeated three times to remove miscella trapped between particles. The flour was recovered, and the solvent was removed by evaporation under a hood for 24 h. The defatting extraction process was repeated with seven 110-g flour samples, and the defatted flour was combined.

Toasting. Defatted flour was toasted with live steam for 10 min at 100°C in a preheated sterilizer autoclave and air dried for 24 h (8).

Soy protein concentrate preparation. Neutralized acid-extracted SPC was prepared by the method of Miller and Wilding (9). Ethanol-extracted SPC was prepared by the method of Baker *et al.* (10) with 70% ethanol at 25°C. Protein concentrates were also prepared from commercially produced soy flakes (Central Soya).

Chemical analysis. The dry weight (11) and protein content of the defatted flour, toasted flour, flakes and concentrates were measured in triplicate. Protein content was measured as Kjeldahl nitrogen multiplied by the factor 6.25. Total lipids were measured by Boatwright and

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Snyder's modification (12) of the method of Bligh and Dyer (13). Phospholipid content was determined from the phosphorus content (14) by using 25 as the conversion factor.

Sensory analysis. Sensory evaluation of the soy flour, toasted soy flour, soy flakes and soy concentrates was performed according to Honig *et al.* (8) by eleven trained panelists. Overall odor and flavor intensities of the samples were based on a 10-point scale in which 1 was bland and 10 was strong. The flavor and odor intensity values for the descriptors, grassy, cooked beany, astringent and bitter, were rated by panelists as 0 for none, 1 for weak, 2 for moderate and 3 for strong. All samples were tested as a 2% dispersion in filtered bottled water. Three samples were presented at random at each tasting to prevent position bias. Samples were evaluated for odor and then for flavor in order of increasing odor intensity.

The sensory panel was trained with the following reference standards prepared with filtered bottled water: bitter, 0.04% caffeine; astringent, 0.035% tannic acid; grassy, 2.00% raw soy flour; cooked beany, 100 g soybeans that were cooked in 300 mL water for 20 min and 100 mL of the liquid was then diluted to 200 mL (8). Intensity values for these attributes were on the 3-point intensity scale. Reference standards were presented at each testing session.

Statistical analysis of the data was by analysis of variance with least significant difference (LSD) values based on a 95% confidence level ($P < 0.05$) by using a SAS computer program (15). Flavor and odor data were analyzed separately.

RESULTS AND DISCUSSION

The total lipid, phospholipid and protein content of the soy preparations are shown in Table 1. The laboratory-processed defatted and toasted flours contained significantly more total lipid and phospholipid than did the commercial soy flakes. This is not surprising because less phospholipid is extracted by ambient-temperature flour extraction than by conventional means (3). The protein content of the flakes was slightly, but significantly, greater than that of the flour.

The SPC derived from flour contained significantly more lipid and phospholipid than SPC from flakes, but there was little difference in protein content. In contrast, there was no significant difference in the total lipid, phospholipid or protein content of alcohol-extracted SPC, probably because the alcohol had extracted most of the residual lipid.

The sensory data to compare the flavor and odor of soy flour, commercial soy flakes and the SPC prepared from them are in Table 2. The overall flavor intensity of defatted flour was significantly greater than that of flakes, but the flour was not significantly different from either flour or flakes after toasting. Descriptive odor and flavor evaluation showed the same trend. Grassy flavor and odor in the flour were reduced by toasting to a level not significantly different from that of flakes. However, the cooked beany odor and flavor of defatted flour was significantly less than that of flakes but increased to that of flakes after toasting. There were no significant differences in astringency or bitterness.

There were no significant differences in overall flavor intensity of acid-extracted SPC relative to SPC obtained from commercial soy flakes. Nevertheless, the overall odor intensities of SPC flour preparations were significantly greater than for SPC derived from flakes. The grassy flavor of the defatted flour carried through in acid-extracted SPC. Toasting defatted flour reduced the grassy flavor and odor in flour SPC to that of flake SPC. No differences were observed for any other sensory descriptor for the SPC.

No significant differences were found in the overall flavor intensities of ethanol-extracted SPC. Toasting the flour significantly increased the overall odor intensity for SPC as compared to the SPC from flakes and nontoasted flour. The grassy flavor and odor of the flour-derived SPC were similar to that of SPC from flakes. SPC from defatted flour had significantly less cooked beany flavor than SPC from flakes, but had a similar odor intensity. However, toasting the flour produced SPC with a stronger cooked beany flavor and odor than those obtained from flakes. There were no differences in astringency and bitterness.

TABLE 1

Lipid, Phospholipid and Protein Contents (% of dry wt) of Flours and Soy Protein Concentrates (SPC)[a]

	Percent of dry wt		
Sample	Total lipid	Phospholipid	Protein
Commercial soy flakes (control)	2.78c	1.68c	55.98d
Defatted flour	3.10b	1.90b	54.93e
Toasted defatted flour	3.09b	1.90b	54.67e
Acid-extracted SPC from flakes (control)	3.10b	1.87b	71.34a
Acid-extracted SPC from defatted flour	3.58a	2.39a	70.56b
Acid-extracted SPC from toasted defatted flour	3.75a	2.34a	71.27a
Alcohol-extracted SPC from flakes (control)	0.36d	0.03d	69.82c
Alcohol-extracted SPC from defatted flour	0.42d	0.03d	69.89c
Alcohol-extracted SPC from toasted defatted flour	0.40d	0.05d	70.43cb

[a]Results are the means of triplicate determination that have been subjected to analysis of variance. Readings with the same letter within a column are not significantly different ($P \geq 0.05$).

TABLE 2

Sensory Evaluation of Soy Flour, Commercial Soy Flakes and Acid-Extracted and Ethanol-Extracted Soy Protein Concentrates (SPC) Prepared from the Floor and Flakes

Source	Intensity[a]	Overall grassy	Cooked beany	Astringency	Bitter
			FLAVOR		
Soy flour and commercial flakes					
Soy flakes (control)	3.6b	0.8b	1.1a	0.9a	0.6a
Defatted soy flour	5.4a	2.0a	0.3b	0.8a	0.4a
Toasted defatted soy flour	4.6ab	0.5b	1.4a	0.8a	0.7a
			ODOR		
Soy flakes (control)	2.4b	0.3b	0.8a		
Defatted soy flour	4.6a	1.1a	0.1b		
Toasted defatted soy flour	3.0b	0.3b	1.0a		
			FLAVOR		
Acid-extracted SPC					
Soy flakes (control)	2.6c	0.2d	0.7c	1.0c	0.5c
Defatted soy flour	3.6c	0.8c	0.6c	1.0c	0.7c
Toasted defatted soy flour	3.2c	0.0d	1.1c	1.1c	0.6c
			ODOR		
Soy flakes (control)	1.0d	0.0d	0.7c		
Defatted soy flour	2.7c	0.7c	0.8c		
Toasted defatted soy flour	2.3c	0.1d	1.1c		
			FLAVOR		
Ethanol-extracted SPC					
Soy flakes (control)	2.8e	0.3ef	0.5f	0.9e	0.7e
Defatted soy flour	2.3e	0.5e	0.2g	0.7d	0.6e
Toasted defatted soy flour	3.0e	0.1f	1.1e	0.7e	0.6e
			ODOR		
Soy flakes (control)	1.0f	0.1e	0.3f		
Defatted soy flour	0.5f	0.1e	0.2f		
Toasted defatted soy flour	3.2e	0.0e	1.3e		

[a]Data with the same letter in the same column are not significantly different ($P \geq 0.05$).

In conclusion, SPC from defatted soy flour and toasted defatted soy flour from the equilibrium extraction were similar in lipid and protein composition to SPC made from commercial flakes. Ethanol extraction produced SPC with protein and lipid content more like commercial soy flakes than those obtained with acid extraction. Acid-extracted SPC had higher total lipid content than did ethanol-extracted SPC, probably because ethanol removed additional lipids. Differences in flavor and odor of acid-extracted flake and flour SPC were small and probably due to unextracted phospholipids. Toasted soy flour had similar sensory properties to those of soy flakes. Similarly, ethanol-extracted SPC from toasted flour and flakes were not different in overall flavor intensity or in any flavor descriptors, except for a cooked beany flavor. Thus, SPC was produced from defatted flour by ambient-temperature extraction that was comparable with SPC obtained from food-grade soy flakes.

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REFERENCES

1. Gunstone, F.D., and F.A. Norris, in *Lipids in Foods, Chemistry, Biochemistry, and Technology*, Chapter 11, Pergamon Press, London, 1983.
2. Sheu, G., Analysis of Soybean Varieties for Oil and Pigments by a New Rapid Method, Masters Thesis, University of Arkansas, Fayetteville, 1987.
3. Clark, P.K., and H.E. Snyder, *J. Am. Oil Chem. Soc. 66*:1316 (1989).
4. Snyder, H.E., K.L. Wiese, G. Sheu, H.G. Brown, C. Nieh and P.K. Clark, U.S. Patent 5,085,808 (1992).
5. *Official and Tentative Methods and Recommended Practices of the American Oil Chemists' Society*, edited by R.C. Walker, American Oil Chemists' Society, Champaign, 1985, Method Ac 3-44.
6. Nieh, C.D., and H.E. Snyder, *J. Am. Oil Chem. Soc. 68*:251 (1991).
7. *Official and Tentative Methods and Recommended Practices of the American Oil Chemists' Society*, edited by R.C. Walker, American Oil Chemists' Society, Champaign, 1985, Method Ba 11-65.
8. Honig, D.H., K. Warner, and J.J. Rackis, *J. Fd. Sci. 41*:642 (1976).

9. Miller, D.M., and M.D. Wilding, U.S. Patent 3,723,407 (1973).
10. Baker, E., G.C. Mustakas and K. Warner, *J. Agric. Food Chem. 27*:969 (1979).
11. *Official Methods of Analysis of the Association of Official Analytical Chemists*, 15th edn., edited by Kenneth Heluck, Association of Official Analytical Chemists, Inc., Arlington, 1990, Method 960.52.
12. Boatwright, W.L., and H.E. Snyder, *J. Am. Oil Chem. Soc. 70*:623 (1993).
13. Bligh, E.G., and W.J. Dyer, *Can. J. Biochem. Physiol. 37*:911 (1959).
14. Bartlett, G.R., *J. Biol. Chem. 234*:446 (1959).
15. SAS/STAT™, SAS Institute Inc., Cary, North Carolina, 1985.

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