Baking Properties of Oilseed Protein and Isolates Produced with Industrial Membrane Systems[1]

M. N. KHAN[2] and J. T. LAWHON[3]

Cereal Chem. 57(6):433–436

ABSTRACT

Blends of wheat flour and protein isolates prepared from soy, cottonseed, and peanut flours by an alkaline extraction and ultrafiltration process were used to make bread by a short-time dough, white pan bread formula. Bread with acceptable volume was obtained when 4% soy or 8% cottonseed or peanut isolate was included in the formula. The protein isolate obtained by $Ca(OH)_2$ extraction of untoasted defatted soy or peanut flour produced better bread with higher loaf volume than did the other six isolates. No significant difference was found in the baking properties of breads made from the two cottonseed isolates. Breads containing the soy protein isolates had superior crumb properties to the ones made from the peanut or cottonseed isolates.

Extensive literature exists on the fortification of white pan bread with oilseed protein products (Khan et al 1975, 1976; Rooney et al 1972; Tsen et al 1971). Many commercial companies make soy protein products to be included in bread and other baked products. The majority of U.S. baking companies are using soy flour as a complete or partial replacement for milk in a white pan bread formula. Soy flour is also used in some of the variety breads made in the United States. Recently, peanut and cottonseed proteins have been added to the list of vegetable proteins used for protein fortifications in various food systems. The protein content of a white pan bread can now be increased by 40–50% by including an oilseed protein product made from soy or peanut (Khan et al 1975, Tsen et al 1971).

The success of an oilseed protein in a bread formula depends on the kind of oilseed and the method of processing the oilseed protein (Khan et al 1975, Rooney et al 1972). Conventional procedures used in preparing an oilseed protein isolate present two fundamental problems: 1) they are costly, and 2) the by-products such as wheys or wheylike products constitute a serious pollution problem (Lawhon et al 1977). However, semipermeable ultrafiltration (UF) and reverse osmosis membranes have been used successfully in preparing oilseed protein isolates from oilseed flour extracts (Lawhon et al 1978). The idea was adopted from the cheese industry, in which these membrane systems have been used successfully to process cheese wheys (Horton[4]) and substantially reduce the pollution problem. The objective of the work reported here was to evaluate the baking properties of soy, cottonseed, and peanut protein isolates produced with UF membranes.

MATERIALS AND METHODS

Preparation of Ultrafiltration Products

Seven experimental products were produced by UF. Two soy protein isolates (SPI) were prepared by a membrane-isolated process from an untoasted commercial soy flour. These isolates, SPI_1 and SPI_2, were extracted with NaOH and $Ca(OH)_2$, respectively. A third soy isolate (SPI_3) was prepared from a partially-toasted commercial soy flour, using $Ca(OH)_2$ for protein disperson at pH 9. (A commercial soy protein isolate (CSPI) was used for comparison.) Two peanut protein isolates (PPI) were

[1]Joint contribution of the Cereal Quality Laboratory, Soil and Crop Sciences Department, and the Food Protein Research and Development Center, Texas A&M University, College Station, TX.
[2]Research scientist, Cereal Quality Laboratory.
[3]Research engineer, Food Protein Research and Development Center.

0009-0352/80/06043304/$03.00/0

[4]B. S. Horton. 1974. Ultrafiltration of whey and milk for protein recovery. Presented at the IV International Congress of Food Sciences and Technology, Madrid, Spain (Sept.).

TABLE I
Proximate Analysis of Oilseed Protein Products and Wheat Flour[a]

Sample[b]	Ash	Nitrogen Total	Nitrogen NPN[c]	Protein[d] (N × 6.25)	Total Sugars	Total P	Color[e] Dry	Color[e] Wet
SPI_1	5.6	14.98	0.52	93.6	6.4	0.68	83.1	53.4
SPI_2	6.3	14.96	0.25	92.3	5.5	1.15	84.5	66.8
SPI_3	7.7	13.74	0.41	85.9	4.6	1.13	80.7	62.5
CSPI	4.0	14.70	0.21	91.8	4.1	0.60	82.5	66.3
CPI_1	6.7	12.34	0.70	77.1	19.3	1.97	75.2	56.6
CPI_2	3.2	16.33	0.46	102.0	2.4	0.87	67.9	51.6
PPI_1	4.0	15.87	0.46	99.2	5.2	0.58	79.6	70.0
PPI_2	2.3	16.01	0.34	100.0	1.97	0.23	77.9	66.3
Wheat flour	···	2.28	···	13.0[f]	···	···	···	···

[a] Fat content of samples was less than 0.5%.
[b] SPI_1 = isolate extracted with NaOH from untoasted soy flour, SPI_2 = isolate extracted with $Ca(OH)_2$ from untoasted soy flour, SPI_3 = isolate extracted with $Ca(OH)_2$ from toasted soy flour, CSPI = commercial soy protein isolate, CPI_1 = cottonseed nonstorage protein isolate, CPI_2 = cottonseed storage protein isolate, PPI_1 = isolate extracted with NaOH from peanut flour, PPI_2 = isolate extracted with $Ca(OH)_2$ from peanut flour.
[c] Nonprotein nitrogen.
[d] Percent dry weight basis.
[e] "L" value of Hunter Lab Color Difference Meter.
[f] N × 5.7.

TABLE II
Essential Amino Acid Pattern (Percent of Protein) of the Typical Soy, Peanut, and Cottonseed Protein Isolates Prepared with Ultrafiltration Membrane Systems

Essential Amino Acid	Isolate Soy	Cottonseed[a] CPI_1	Cottonseed[a] CPI_2	Peanut
Lysine	5.95	7.50	2.96	2.96
Tryptophan	1.59	1.67	1.02	0.89
Cystine	1.94	3.27	1.64	2.00
Threonine	3.32	4.26	2.47	2.37
Valine	4.36	4.72	4.02	4.23
Methionine	0.18	3.19	0.84	···
Isoleucine	4.41	3.19	3.34	3.58
Leucine	7.26	5.66	6.71	7.22
Phenylalanine	4.97	3.47	5.17	1.13
Available Lysine	5.81	7.24	2.73	2.58

[a] CPI_1 = nonstorage proteins, CPI_2 = storage proteins.

produced from defatted commercial peanut flour. NaOH and $Ca(OH)_2$ were used to extract the peanut products, designated PPI_1 and PPI_2, respectively.

Nonstorage protein (NSP) and storage protein (SP) were extracted separately from glandless cottonseed flour prepared at the Food Protein Research and Development Center, Texas A&M University, and the extracts were processed separately to produce two cottonseed protein isolates (CPI), an NSP concentrate (CPI_1) and an SP isolate (CPI_2), as reported elsewhere (Lawhon et al 1977). Water was used to extract the NSP, whereas NaOH at pH 10 was used to extract the SP.

Procedures used for soy flour extraction have been reported previously (Lawhon et al 1978, 1979). Procedures for peanut extractions were essentially the same as for soy.

Analytical Data

The oilseed protein isolates were analyzed with standard AOCS (1971) procedures for total nitrogen, nonprotein nitrogen, fat, ash, total sugars, and total P. Color readings of the protein products were determined with the Hunter Lab Color Difference Meter, using "L" values. Amino acid analysis (except tryptophan) was carried out by the procedure of Spackman et al (1958). Tryptophan was determined by the method of Kohler and Palter (1967).

Physical Dough and Baking Properties

Preparation of Blends. Wheat flour was replaced with 4% soy protein isolate or with 8% peanut or cottonseed protein isolates. These concentrations were established after evaluating a series of each of the isolates in a preliminary experiment.

Baking Properties. Preliminary experiments indicated that bread with acceptable volume could be made with 4% SPI or with 8% CPI or PPI. More than 4% SPI produced poor dough-handling properties and unacceptable bread. A detailed experiment was therefore conducted with pound loaves made by a short-time dough system according to the method described by Khan et al (1975). Sodium stearoyl lactylate at 1% was included in the formula.

All of the flour blends were baked on the same day, and the entire experiment was repeated on each of three days in a randomized complete-block design. A statistical analysis of variance was performed on the data. Duncan's multiple range test was used to separate the means.

Loaf volume was measured by rape seed displacement immediately after baking. The crumb grain score, texture, and crumb color were measured 18 hr later. The "L" value of the Hunter Lab Color Difference Meter was used to describe crumb color.

RESULTS AND DISCUSSION

Chemical Composition of Protein Products

Protein content (N × 6.25) of the experimental soy protein products ranged from 86 to 93%; CSPI had a protein content of 92% (Table I). SPI_3 had a lower protein content than did SPI_2. The ash content of SPI_3 was substantially higher than those of the other SPIs, perhaps because of the significant reduction of protein content in the isolate. SPI_3 was also slightly darker as a result of the toasting it received during processing. Sugar contents of CSPI and SPI_3 were somewhat less than those of the other two SPIs. Protein content of CPI_1 was less and ash and sugar content were higher than those of CPI_2. CPI_1 was different from the cottonseed NSP product reported by Lawhon et al (1974), which was obtained by ultrafiltering NSP cottonseed whey. It contained a considerably higher sugar and ash content than did CPI_1. The color of the dry CPI_2 was darker than that of CPI_1.

The ash and sugar contents of PPI_1 were higher and its color was darker than those of PPI_2. Protein contents of both PPIs were the same.

The essential amino acid pattern (Table II) of all four SPI were the same. Except for the isoleucine, leucine, and the phenylalanine, the essential amino acids of CPI_1 were significantly higher than those of any other isolate.

Baking Properties

Baking data for breads made with protein isolates are presented in Table III. Photographs of the breads are presented in Figs. 1–3.

TABLE III
Baking Properties of Wheat Flour-Oilseed Protein Isolate Blends

Sample[a]	Percent Protein Isolate	Loaf Volume (cc)	Specific Loaf Volume (cc)	Crumb Properties Grain[b]	Texture[b]	Color[c]
SPI_1	4	2,850 d[d]	6.04 e	80 a	73.3 abc	78.4 a
SPI_2	4	3,250 b	6.64 bc	73.3 a	81.7 a	78.8 a
SPI_3	4	3,083 c	6.57 cd	70.0 ab	70.0 abc	77.8 a
CSPI	4	3,058 c	6.46 cde	63.3 ab	65.0 bc	78.3 a
CPI_1	8	2,875 d	6.10 e	68.3 ab	65.0 bc	72.1 c
CPI_2	8	2,883 d	6.13 de	63.3 ab	65.0 bc	70.2 d
PPI_1	8	3,025 c	6.30 cde	63.3 ab	71.7 abc	74.4 b
PPI_2	8	3,308 ab	7.02 ab	53.3 b	63.3 c	74.6 b
Control	0	3,048 a	7.16 a	73.3 a	76.7 ab	79.0 a

[a] SPI_1 = isolate extracted with NaOH from untoasted soy flour, SPI_2 = isolate extracted with $Ca(OH)_2$ from untoasted soy flour, SPI_3 = isolate extracted with $Ca(OH)_2$ from toasted soy flour, CSPI = commercial soy protein isolate, CPI_1 = cottonseed nonstorage protein isolate, CPI_2 = cottonseed storage protein isolate, PPI_1 = isolate extracted with NaOH from peanut flour. PPI_2 = isolate extracted with $Ca(OH)_2$ from peanut flour.
[b] Subjective evaluation.
[c] "L" value of Hunter Lab Color Difference Meter. 0 = black, 100 = white.
[d] Means followed by the same letter were not significantly different from each other at the 5% level of significance.

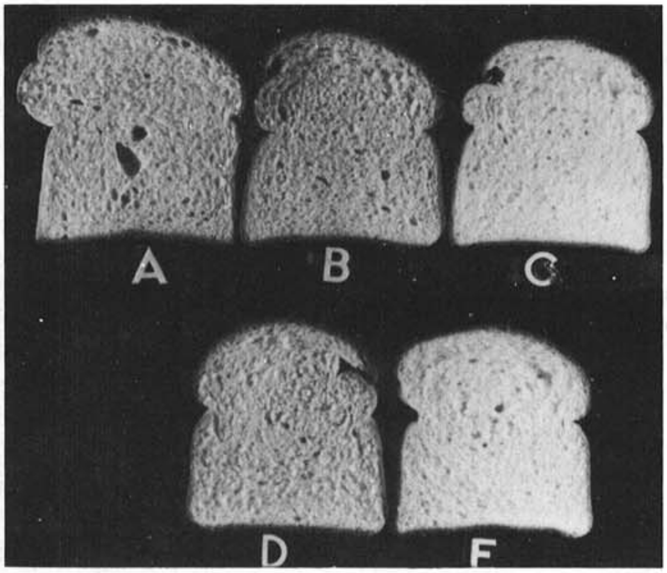

Fig. 1. Pound loaves of bread made by short-time dough procedure with soy protein isolate substituted for wheat flour. **A** = 100% wheat flour, **B** = 4% isolate extracted with NaOH from untoasted soy flour, **C** = 4% isolate extracted with $Ca(OH)_2$ from untoasted soy flour, **D** = 4% commercial soy isolate, **E** = 4% isolate extracted with $Ca(OH)_2$ from toasted soy flour.

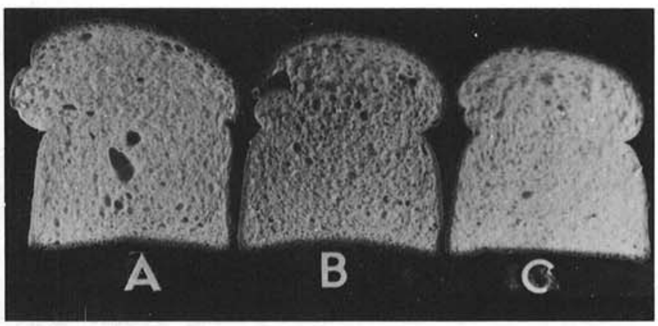

Fig. 2. Pound loaves of bread made by short-time dough procedure with cottonseed protein isolate substituted for wheat flour. **A** = 100% wheat flour, **B** = 8% nonstorage protein isolate from cottonseed flour, **C** = 8% storage protein isolate from cottonseed flour.

The mixing times of doughs containing any of the SPIs were measurably longer (7–8 min) than those containing the CPIs or PPIs (3–4 min). Dough proof times of all the blends (56–60 min), except the one containing CPI_1 (65 min), were comparable to that

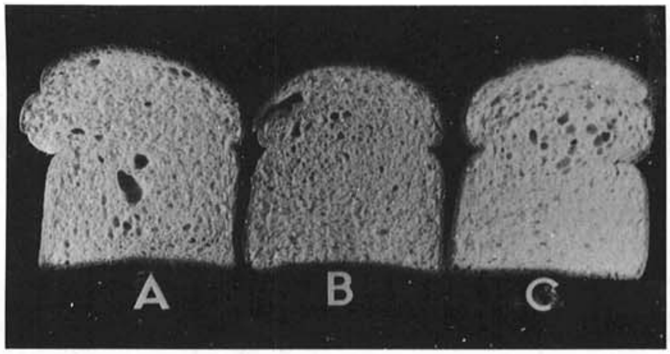

Fig. 3. Pound loaves of bread made by short-time dough procedure with peanut protein isolate substituted for wheat flour. **A** = 100% wheat flour, **B** = 8% isolate extracted with NaOH from peanut flour, **C** = 8% isolate extracted with $Ca(OH)_2$ from peanut flour.

(60 min) of the control, a wheat flour dough. The longer proof time of CPI_1 was the result of its high sugar content. However, the dough handling properties of the blend containing CPI_1 were considerably better than those of the dough containing cottonseed NSP product reported by Lawhon et al (1974).

$Ca(OH)_2$ extraction of SPI_2 significantly improved its baking properties over those of SPI_1, SPI_3, and CSPI. Bread made with SPI_2 had significantly higher loaf volume than did the other SPIs. The use of toasted flour in preparation of SPI_3 reduced its loaf volume potential significantly compared to that of SPI_2. However, its loaf volume was higher than that of SPI_1, an isolate prepared using NaOH.

Loaf volume and crumb characteristics of the breads made with either of the CPIs were acceptable. The high sugar content of CPI_1 did not affect its bread-making properties. The breads made with the PPIs had good loaf volume. In fact, the bread containing PPI_2 had the highest loaf volume among all protein isolates, although it was not statistically different from that of SPI_2. However, the texture of the bread was very tough and its grain was open. The crumb characteristics of bread made with PPI_2 could perhaps be improved by dough conditioners other than the sodium stearoyl lactylate used here.

In general, PPI at 8% substitution had better baking properties than did CPI 8% and SPI at 4%. However, CPI at 8% substitution markedly increased the quality and quantity of the protein in white pan bread. Lysine content was increased by more than 100%.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1970. Approved Methods of the AACC. St. Paul: MN.
AMERICAN OIL CHEMISTS SOCIETY. 1971. Official and Tentative

Methods (3rd ed.). The Society: Chicago, IL.
KHAN, M. N., LAWHON, J. T., ROONEY, L. W., and CATER, C. M. 1976. Bread-baking properties of cottonseed protein concentrates prepared from solvent-extracted glandless cottonseed flour. Cereal Chem. 53:388.
KHAN, M. N., RHEE, K. C., ROONEY, L. W., and CATER, C. M. 1975. Bread making properties of aqueous processed peanut protein concentrates. J. Food Sci. 40:580.
KOHLER, G. O., and PALTER, R. 1967. Studies on methods for amino acids analysis of wheat products. Cereal Chem. 44:512.
LAWHON, J. T., HENSLEY, D. W., MIZUKOSHI, M., and MULSOW, D. 1979. Alternate processes for use in soy protein isolation by industrial ultrafiltration membranes. J. Food Sci. 44:213.
LAWHON, J. T., HENSLEY, D. W., MULSOW, D., and MATTIL, K. F. 1978. Optimization of protein isolate production from soy flour using industrial membrane systems. J. Food Sci. 43:361.
LAWHON, J. T., LIN, S. H. C., ROONEY, L. W., CATER, C. M., and MATTIL, K. F. 1974. Utilization of cottonseed whey protein concentrates produced by ultrafiltration. J. Food Sci. 39:183.
LAWHON, J. T., MULSOW, D., CATER, C. M., and MATTIL, K. F. 1977. Production of protein isolates and concentrates from oilseed flour extracts using industrial ultrafiltration and reverse osmosis systems. J. Food Sci. 42:389.
ROONEY, L. W., GUSTAFSON, C. B., CLARK, S. P., and CATER, C. M. 1972. Comparison of the baking properties of several oilseed flours. J. Food Sci. 37:14.
SPACKMAN, D. J., STEIN, W. H., and MOORE, S. 1958. Automatic recording apparatus for use in the chromatography of amino acid. Anal. Chem. 30:1190.
TSEN, C. C., HOOVER, W. J., and PHILLIPS, D. 1971. High protein breads: Use of sodium stearoyl-2-lactylate and calcium stearoyl-2-lactylate in their production. Bakers Dig. 45(2):20.

[Received April 3, 1980. Accepted July 9, 1980]