Effects of Addition of Great Northern Bean Flour and Protein Concentrates on Rheological Properties of Dough and Baking Quality of Bread[1]

S. K. SATHE,[2] J. G. PONTE, Jr.,[3] P. D. RANGNEKAR,[3] and D. K. SALUNKHE[2]

Cereal Chem. 58(2):97–100

ABSTRACT

Proteins from the Great Northern bean (*Phaseolus vulgaris* L.) were concentrated. The rheological and baking properties of a blend of wheat flour and protein concentrates were compared with those of a blend of wheat flour and bean flour. Addition of the bean flour or protein concentrates to wheat flours caused an increase in water absorption and a decrease in mixing time, dough stability, and mixograph peak height. Load-extension curves for wheat flour/bean flour blends indicated a decreased resistance to extension with increased concentration of the bean flour. For a fixed bean flour level in the blend, however, resistance to extension increased with an increase in resting time. Addition of the bean flour at levels above 10% was detrimental to the dough and bread quality. Breads prepared with added protein concentrates (≤ 10%) were more acceptable than those prepared with added bean flour (≤ 10%), however.

In the United States, beans (*Phaseolus vulgaris* L.) are an important food crop in terms of both economics and nutrition. They contain about 25–30% proteins on a dry weight basis and are isocaloric to cereals. Great Northern beans rank third among the five major bean cultivars, navy, pinto, Great Northern, kidney, and lima (Chang and Satterlee 1979). Cereals are deficient in lysine, whereas dry beans are rich lysine sources. Cereal-bean blends thus complement each other by improving the essential amino acid balance. Bakery products (particularly breads) are universally acceptable foods and thus offer a valuable vehicle for nutritional improvement.

Several investigators have reported studies on wheat flour-legume flour blends for bread making. Legumes employed for such studies include soybeans (Pomeranz et al 1969a, Tsen and Hoover 1973, Tsen and Tang 1971), chickpea (Shehata and Fryer 1970), broad beans (Hussein et al 1974), peas (Jeffers et al 1978), fababeans (Lorenz et al 1979), navy beans (D'Appolonia 1978), and others (D'Appolonia 1977). Recently, Sosulski and Fleming (1979) reported that acceptable breads can be produced by replacing 15% wheat flour with plant protein concentrates and 2% with vital gluten, using 1% surfactant in addition to 3% shortening. The incorporation of high proportions of foreign proteins into bread doughs can cause severe deterioration of loaf volume, crumb characteristics (crumb grain and compressibility), and palatability. This often necessitates the addition of dough conditioners such as lactylate esters (Tsen and Hoover 1973) and glycolipids (Pomeranz et al 1969b).

Relatively few investigations, however, have been made on bread making using dry bean protein concentrates. The protein concentrates can increase protein more (weight for weight replacement) than can bean flour. Earlier, Sathe and Salunkhe (1981) reported solubilization and electrophoretic characterization of the Great Northern bean proteins. The purpose of the present investigation was to compare the effects of incorporation of the Great Northern bean flour and of protein concentrates on the rheological properties of dough and the baking quality of bread.

MATERIALS AND METHODS

The Great Northern beans were purchased from Bean Growers' Warehouse, Filer, ID, and stored at 4°C until experiments were conducted. Beans were ground in a Fitz mill (W. J. Fitzpatrick Co., Chicago, IL) to pass a 20-mesh sieve thus obtaining bean flour (BF). Two different wheat flours were employed, an all purpose wheat flour purchased from a local market (APWF) and a hard winter wheat (Scout 66, Kansas Control 79-716) flour (WF). Unless otherwise mentioned, all chemicals were of reagent grade. All the analyses were performed in duplicate and the means reported.

Preparation of Protein Concentrates

Protein concentrates were prepared from BF on laboratory as well as pilot plant scale. Preparation of protein concentrates on laboratory scale (PC) involved extraction of the BF with 0.5% Na_2CO_3 (w/v) for 24 hr at 4°C (BF/solvent, 1:10, w/v) followed by centrifugation (10,000 × *g*, 30 min), dialysis (48 hr against distilled water, six changes of distilled water), and lyophilization.

Pilot plant scale preparation of protein concentrates (CPC) was as follows. Eight kilograms of BF was extracted in 0.5% Na_2CO_3 aqueous solution (BF/solvent, 1:10, w/v) at 21°C for 30 min (with hand stirring with a wooden spatula) and centrifuged at 5,000 × *g* in a continuous centrifuge (Beehive Machinery Inc., Sandy, UT). The supernatant was then ultrafiltered (molecular weight cut-off about 35,000) at 50°C and 90 psi and lyophilized.

Protein Determination

Protein content was determined by standard AACC method 46-11 (1961). Conversion factors were 6.25 for BF, CPC, and PC and 5.7 for wheat flours.

Blends

BF replaced 5, 10, 15, 20, 25, 30, 35, and 40% (by weight) of each wheat flour. The protein concentrates replaced 5, 10, and 15% (by weight) of each wheat flour.

Dough Rheology

Farinograph. The Brabender farinograph equipped with 50-g bowl and the constant flour weight procedure of the AACC method 54-21 (1976) were employed to study mixing time, dough stability, and mixing tolerance index of the wheat flour blends.

Mixograph. The 10-g mixograph method of Finney and Shogren (1972) was used for the evaluation of physical dough mixing properties.

Extensigraph. The blends were evaluated for resistance to extension and extensibility by the AACC method 54-10 (1976). Load-extension curves were recorded at 45, 90, 135, and 180-min rest periods. Blends with CPC and PC were not evaluated due to their limited quantities.

Baking

WF was employed for the preparation of breads. The pup loaf method (straight dough) of Finney et al (1976) was followed. The formula was: wheat flour/blend (14% mb), 100 g; shortening, 3 g; nonfat dry milk, 4 g; sugar, 6 g; salt, 1.5 g; yeast, 2.12 g; ascorbic acid, 100 ppm; $KBrO_3$, 20 ppm; and water, optimum.

[1]Contribution 2530 from the Department of Nutrition and Food Sciences, Utah State Agricultural Experiment Station, Utah State University, Logan 84322. Contribution 80-303-j from the Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Kansas State University, Manhattan 66506.

[2]Graduate research assistant and professor, respectively. Department of Nutrition and Food Sciences, Utah State University.
[3]Professor and graduate research assistant, respectively. Department of Grain Science and Industry, Kansas State University.

009-0352/81/0209704/$03.00/0

TABLE I
Farinograph Data for APWF and WF Blends with BF, CPC, and PC[a]

Blend and Replacement Percent	Water Absorption (%)		Arrival Time (min)		Mixing Time (min)		Stability (min)		Mixing Tolerance Index (BU)	
	APWF	WF	APWF	WF	APWF	WF	APWF	WF	APWF	WF
BF 0	56.0	61.7	1.0	2.2	5.3	5.5	8.0	14.1	60	40
5	57.8	64.4	1.5	2.3	5.0	5.5	6.5	9.7	70	60
10	60.0	66.0	2.3	2.8	5.0	5.3	4.5	6.8	80	70
15	62.1	68.8	2.5	3.3	4.5	5.0	4.5	4.0	80	70
20	64.8	70.6	2.5	3.1	4.3	4.3	3.8	3.4	100	80
25	66.7	71.9	2.5	3.1	3.8	4.3	3.3	3.4	120	75
30	69.3	74.0	2.8	3.2	4.0	4.2	2.5	2.8	130	80
35	71.0	76.0	3.0	3.5	4.0	4.3	1.8	2.4	130	110
40	72.8	77.0	3.3	3.3	4.2	4.3	2.2	2.5	135	120
CPC 5	60.5	66.9	4.5	4.3	6.8	9.0	4.5	12.0	40	40
10	65.0	72.7	4.0	9.5	6.8	10.0	6.5	8.5	30	50
15	69.1	77.7	5.0	8.0	6.8	10.5	3.8	6.8	60	40
PC 5	61.1	67.8	2.3	4.3	4.3	6.8	4.7	5.8	90	60
10	66.0	73.7	2.5	5.2	4.0	7.3	2.3	4.3	95	60
15	69.8	78.7	1.0	4.2	3.5	7.0	5.0	5.3	85	70

[a] APWF = All purpose wheat flour, WF = Scout 66 wheat flour, BF = Great Northern bean flour, CPC = protein concentrates (pilot plant scale), PC = protein concentrates (laboratory scale).

TABLE II
Mixograph Data for APWF and WF Blends with BF, CPC, and CP[a]

Blend and Replacement Percent	Water Absorption (%)		Mixing Time (min)		Peak Height (cm)	
	APWF	WF	APWF	WF	APWF	WF
BF 0	56.0	63.0	4.2	4.3	5.1	5.7
5	58.0	64.5	4.5	3.5	4.6	5.6
10	60.0	65.5	4.5	3.6	4.6	6.0
15	62.0	67.0	4.0	3.8	4.0	5.3
20	65.5	67.5	4.0	4.0	3.8	5.3
25	66.0	68.5	4.0	4.1	3.7	5.0
30	67.0	69.9	4.0	4.0	3.6	4.8
35	67.5	73.0	3.5	3.9	3.6	4.0
40	67.0	74.5	3.0	···	3.1	···
CPC 5	62.5	70.0	4.8	4.6	4.5	5.6
10	64.0	71.0	4.4	4.5	3.8	4.8
15	64.5	71.5	···	···	···	···
PC 5	59.5	67.5	3.7	4.0	4.2	5.6
10	60.0	69.0	3.0	3.5	4.2	5.3
15	62.5	70.0	···	···	···	···

[a] APWF = All purpose wheat flour, WF = Scout 66 wheat flour, BF = Great Northern bean flour, CPC = protein concentrates (pilot plant scale), PC = protein concentrates (laboratory scale).

The doughs were mixed for optimum dough development (point of minimum mobility) and fermented at 30°C and 92–95% rh for 180 min. Doughs were punched at 105 and 155 min, proofed for 55 min (30°C and 92–95% rh), and baked at 215°C for 24 min.

Bread Evaluation

Freshly baked breads were evaluated for loaf volume by the rapeseed displacement method and loaf weight. Subjective evaluation for crumb, crust, taste, and flavor was conducted after the breads were cooled at room temperature (21°C) for 1 hr. The taste panel consisted of five trained personnel. The taste panel scores were assigned on the following scale: excellent, 1; very good, 2; fair, 3; poor, 4; and very poor, 5.

The samples were scored with reference to the control bread, of which the score was 1. Breads were stored at 4°C for 48 hr, brought to room temperature (21°C), and photographed.

RESULTS AND DISCUSSION

The blends prepared from both the wheat flours and BF, CPC, and PC were studied for their rheological properties. Protein contents of BF, CPC, PC, APWF, and WF were 26.1, 77.7, 85.4, 11.7, and 14.7%, respectively, on dry weight basis.

Dough Rheology

Farinograph. Farinograph results of APWF and WF blends with BF, CPC, and PC are presented in Table I. WF had higher water absorption than did APWF. In all cases, water absorption increased with increasing levels of BF, CPC, or PC additions, whereas mixing time and dough stability had decreasing trends. The WF blends with BF, CPC, or PC had better dough stability than did the blends of APWF with BF, CPC, or PC. The mixing tolerance index, in general, increased with the increasing levels of BF, CPC, or PC addition. This effect was more pronounced for BF than for CPC or PC in both APWF and WF. Water absorption increase was higher in all blends of WF than in those of APWF. The reduction in dough stabilities and increase in water absorption observed in the present investigation are in agreement with those found by D'Appolonia (1978). He reported that water absorption increased and dough weakening accompanied the addition of navy bean flour to wheat flour. A similar increase in water absorption due to the addition of sweet lupine flour to wheat flour was reported by Campos and El-Dash (1978).

Mixograph. Mixograph data of APWF and WF blends with BF, CPC, and PC are shown in Table II. In general, an increase in concentration of BF, CPC, or PC increased water absorption and decreased mixing time and peak height. The increase in water absorption attributable to the addition of BF in both APWF and WF was similar; however, addition of CPC or PC to WF caused greater water absorption than for APWF, probably because of the higher protein content in the blends containing CPC and PC than in those containing BF. In certain cases (APWF blends with 15% CPC and PC and WF blends with 40% BF and 15% CPC), sticky doughs were obtained. These doughs lacked cohesive properties and tended to adhere to the inside of the mixing bowl. Consequently mixograms for those samples could not be obtained. Similar difficulties have been reported when navy bean flour was added to wheat flours at high levels (D'Appolonia 1978).

Extensigraph. Blends of APWF and WF with BF were evaluated for extensibility and resistance to extension (Figs. 1 and 2). Resistance to extension increased with increase in resting period and decreased with increased concentration of BF for a particular resting period (Fig. 2). The extensibility, on the other hand, decreased with increase in resting period as well as with increase in concentration of BF in the blend. These trends were similar in blends prepared from both APWF and WF with BF (Fig.1). Extensibility of the WF blends was greater than that of the APWF blends, whereas the resistance to extension by the APWF blends was greater than that of the WF blends at corresponding rest period and percent BF in the blend.

Mixing and Fermentation

Doughs with BF at 30–40% and CPC or PC at 10 and 15% concentrations were difficult to handle because they were sticky and wet. During the fermentation process, they became progressively stiffer, however, and no difficulty was encountered in subsequent handling.

Results of baking experiments are presented in Table III. The water absorption and mixing time were different than those arrived at by both farinographs and mixographs. This difference must have been caused by the presence of other ingredients in the baking formula. However, the general trend of increased water absorption with increasing concentration of BF, CPC, or PC was consistent with the observations on corresponding farinographs and mixographs. Proof height, in general, decreased with increasing concentration of BF, CPC, or PC.

Bread Evaluation

Loaf volume (Table III and Fig. 3) decreased with increasing concentration of BF, CPC, or PC except for the samples with 5 and 10% PC. As the concentration of BF increased, the crust color darkened progressively. This effect was more pronounced at BF concentrations of 15–40%. Similar but less striking effects were observed with the addition of CPC and PC. Increased crumb grain roughness accompanied by thickening of cells, increased greyish yellow crumb color, and reduction in break and shred were noted with increased concentrations of BF, CPC, or PC. The differences in volume of PC/WF and CPC/WF blends were probably the result of the different processing conditions employed for the preparation of PC and CPC. In the preparation of CPC, the molecular weight cut-off of the ultrafiltration process was about 35,000, whereas that of the dialysis in the preparation of CP was about 8,000. The small molecular weight proteins might therefore have been removed through ultrafiltration during CPC preparation. Additionally, CPC proteins might have been denatured more than those of PC because higher temperatures

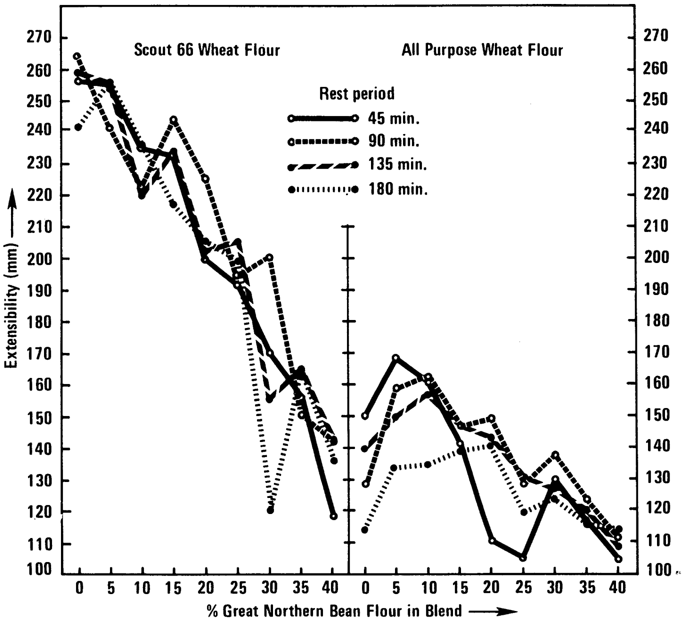

Fig. 1. Extensigraph data for the wheat flour/Great Northern bean flour blends: Extensibility.

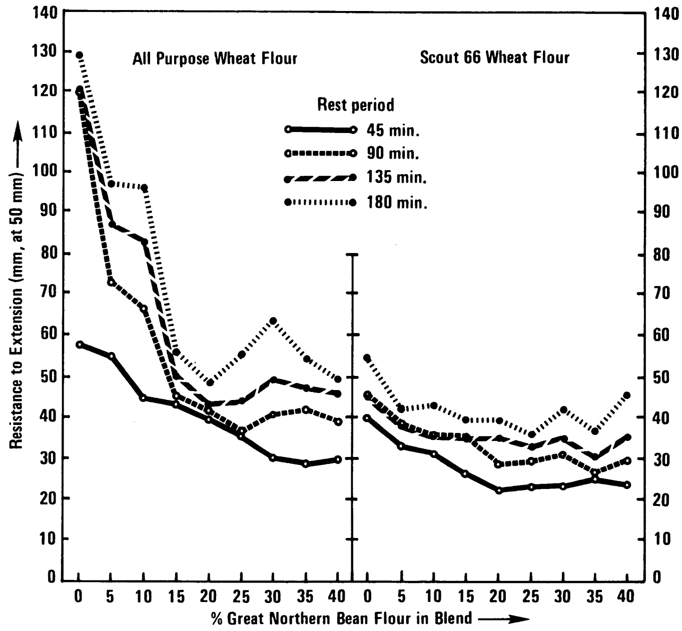

Fig. 2. Extensigraph data for the wheat flour/Great Northern bean flour blends: Resistance to extension.

TABLE III
Baking Data for WF Blends with BF, CPC, and PC[a]

Blend	Replacement Percent	Water Absorption (cc)	Mixing Time (min)	Proof Height (cm)	Loaf Volume (cc)	Loaf Weight (g)	Specific Volume (cc/g)	Taste Panel Score[b]
BF	0	68	4.1	7.50	955.0	142.25	6.57	1.0
	5	67	4.2	7.70	912.5	147.75	6.18	3.0
	10	66	4.3	7.45	840.0	147.35	5.70	4.0
	15	67	4.3	7.30	762.5	148.95	5.12	4.0
	20	67	4.5	7.00	680.0	153.15	4.44	4.0
	25	68	4.4	6.95	602.5	153.15	3.93	4.0
	30	71	5.0	6.90	582.5	157.15	3.71	5.0
	35	73	5.5	6.65	527.5	162.30	3.25	5.0
	40	74	6.0	6.60	490.0	163.00	3.00	5.0
CPC	5	70	4.5	7.70	945.0	156.75	6.03	2.5
	10	71	5.0	7.30	810.0	155.95	5.19	3.0
	15	72	5.5	7.30	632.5	156.65	4.04	4.0
PC	5	67	4.0	7.75	1,032.5	148.90	6.93	2.0
	10	68	4.3	7.85	957.5	149.55	6.40	2.5
	15	69	4.5	7.50	692.5	152.15	4.55	3.5

[a] WF = Scout 66 wheat flour, BF = Great Northern bean flour, CPC = protein concentrates (pilot plant scale), PC = protein concentrates (laboratory scale).
[b] Excellent = 1, good = 2, fair = 3, poor = 4, very poor = 5.

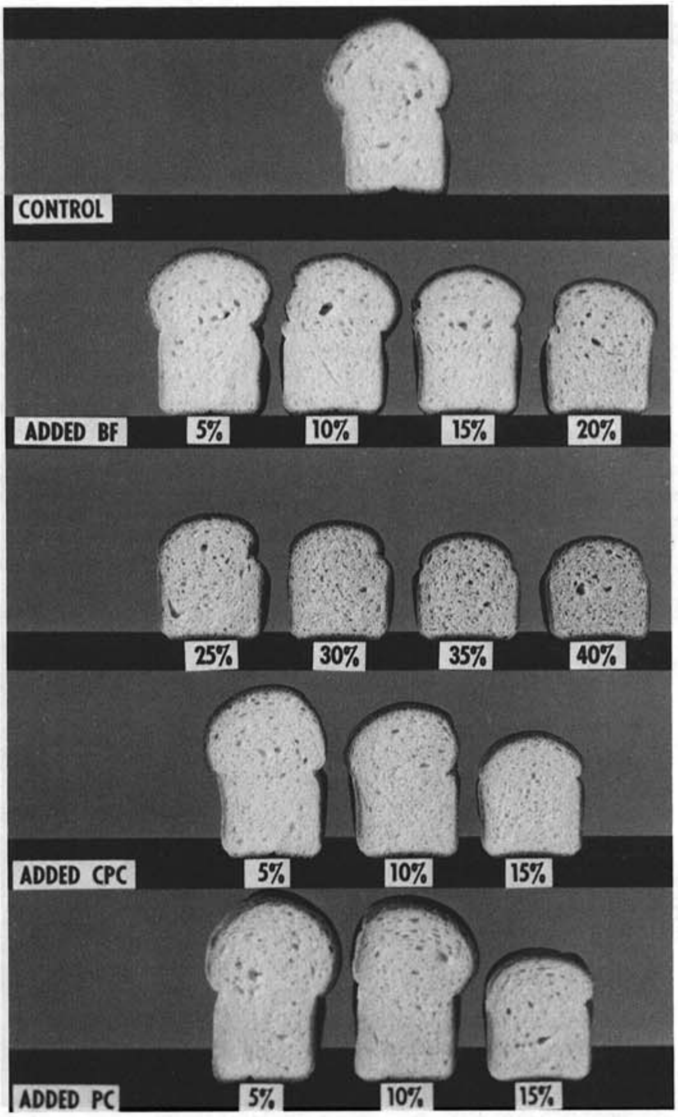

Fig. 3. Breads prepared from Scout 66 wheat flour (control) and its blends with Great Northern bean flour (BF) protein concentrate (pilot plant scale preparation, CPC), and protein concentrate (laboratory scale preparation, PC). Replacement percentages are shown.

were used during CPC preparation.

The taste test revealed that the breads containing BF, CPC, and PC at concentrations greater than 20%, at 10 and 15%, and at 15%, respectively, had a distinctly beany and bitter flavor. Breads containing 5% CPC and 5 and 10% PC registered highest scores among all the experimental samples, indicating that utilization of these inexpensive plant proteins for bread making is possible. Incorporation of protein concentrates offers additional advantage over incorporation of bean flour in that they can increase protein more than bean flour can in weight-for-weight replacement of wheat flour. Sosulski and Fleming (1979) had to replace 2% wheat flour with gluten and also had to use 1% surfactant in addition to 3% shortening in order to incorporate plant protein concentrates into bread. In our investigation, however, replacing WF by CPC (5% by weight) and PC (5 and 10% by weight) could yield breads comparable to or better than the control without the addition of any surfactant or gluten.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of R. C. Hoseney and R. B. Koch, Department of Grain Science and Industry, Kansas State University, in the baking experiments and sensory evaluation of breads and V. T. Mendenhall and C. A. Ernstrom of the Department of Nutrition and Food Sciences, Utah State University, and C. DeSantos of Beehive Machinery Inc., Sandy, UT, for their assistance in the preparation of protein concentrates on pilot plant scale.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of the AACC. Methods 46-11, 54-10, and 54-21, approved April 1961. The Association: St. Paul, MN.

CAMPOS, J. E., and EL-DASH, A. A. 1978. Effect of addition of full-fat sweet lupine flour on rheological properties of dough and bread making quality of bread. Cereal Chem. 55:619.

CHANG, K. C., and SATTERLEE, L. D. 1979. Chemical, nutritional, and microbiological quality of a protein concentrate from culled dry beans. J. Food Sci. 44:1589.

D'APPOLONIA, B. L. 1977. Rheological and baking studies of legume-wheat flour blends. Cereal Chem. 54:53.

D'APPOLONIA, B. L. 1978. Use of untreated and roasted navy beans in bread making. Cereal Chem. 55:898.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flours. Bakers Dig. 45(2):32.

FINNEY, P. L., MAGOFFIN, C. D., HOSENEY, R. C., and FINNEY, K. F. 1976. Short time baking systems. I. Interdependence of yeast concentration, fermentation time, proof time, and oxidation requirement. Cereal Chem. 53:126.

HUSSEIN, L., GABRIEL, G. N., and MORIAS, S. R. 1974. Nutritional value of mixtures of baladi bread and broad beans. J. Sci. Food Agric. 25:1433.

JEFFERS, H. C., RUBENTHALER, G. L., FINNEY, P. L., ANDERSON, P. D., and BRUINSMA, B. L. 1978. Pea: A highly functional fortifier in wheat flour blends. Bakers Dig. 52(3):36.

LORENZ, K., DILSAVER, W., and WOLT, M. 1979. Fababean flour and protein concentrate in baked goods and in pasta products. Bakers Dig. 53(3):39.

POMERANZ, Y., SHOGREN, M. D., and FINNEY, K. F. 1969a. Improving breadmaking properties with glycolipids. I. Improving soy products with sucroesters. Cereal Chem. 46:503.

POMERANZ, Y., SHOGREN, M. D., and FINNEY, K. F. 1969b. Improving breadmaking properties with glycolipids. II. Improving various protein-enriched products. Cereal Chem. 46:512.

SATHE, S. K., and SALUNKHE, D. K. 1981. Solubilization and electrophoretic characterization of the Great Northern bean (Phaseolus vulgaris L.) proteins. J. Food Sci. In press.

SHEHATA, N. A., and FRYER, B. A. 1970. Effect on protein quality of supplementing wheat flour with chickpea flour. Cereal Chem. 47:663.

SOSULSKI, F. W., and FLEMING, S. E. 1979. Sensory evaluation of bread prepared from composite flours. Bakers Dig. 53(3):20.

TSEN, C. C., and HOOVER, W. J. 1973. High protein bread from wheat flour fortified with full-fat soy flour. Cereal Chem. 50:7.

TSEN, C. C., and TANG, R. T. 1971. K-state process for making high protein breads. I. Soy flour bread. Bakers Dig. 45(5):26.

[Received March 14, 1980. Accepted August 18, 1980]