Effects of Soy or Field Pea Flour Substitution on Physical and Sensory Characteristics of Chemically Leavened Quick Breads[1]

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ABSTRACT

The effects of substituting 5, 10, and 15% field pea or defatted soy flour for wheat flour in a chemically leavened quick bread on physical characteristics of batters and breads, and sensory characteristics of breads were studied. Significant differences were observed for batter linespread consistency, loaf volume, darkness, and yellowness values of bread crumbs. No significant differences in redness values or compressibility were seen. A sensory evaluation panel found significant differences among loaves at some substitution levels for the following characteristics: crust color, air cell number, crumb color and color uniformity, and flavor (odor and taste). No significant differences were found among loaves for shape, crust thickness, surface texture, crust texture, crumb texture, tunnels, and mouthfeel. Results indicate that defatted soy flour can be successfully substituted for wheat flour in quick breads at levels up to 15%, whereas at the same substitution levels, field pea flour had adverse effects on both physical and sensory characteristics.

Baked products are consumed worldwide. Therefore, fortification with high-protein legume flours (soy or field pea) provides a good opportunity to improve the nutritional quality of protein consumed by many people (Hoover 1979, Rooney et al 1972). The first limiting amino acid in wheat flour is the essential amino acid lysine (Lemancik and Ziemba 1962). Soybeans and field peas are rich in lysine, and supplementation of wheat flour with either soybean or field pea flour improves the overall protein quality (Anonymous 1974, Bramsnaes and Olsen 1979). In the United States, the largest commercial food usage of soy flour is in bakery products (Hoover 1979). Field pea flour is used most often in thickening of soups (Hannigan 1979).

Much research has been done by substituting various proportions (2.5–20%) of soy or field pea flour into yeast-leavened breads, cakes, cookies, muffins, or biscuits. Studies indicate that 10–15% substitution of these two legume flours could be added to wheat flour to fortify yeast-leavened bread before loaf volume and crumb grain quality become unacceptable (Hannigan 1979). However, research has been limited on the effects of substituting soy flour into a chemically leavened quick bread. Previous reported work on soy-fortified quick bread dealt with soy flours produced on a laboratory scale (Howarter and Klein 1978), rather than a commercially available product.

Pea flour is a relatively new ingredient. It has been substituted on an equivalent protein basis for nonfat dry milk to produce baked products that are free of milk protein (McWatters 1980). It has also been used to supplement wheat protein. Pea flour is an inexpensive form of protein and is easy to make. It is not highly processed, is high in fiber, and has relatively good protein quality and quantity (Hannigan 1979). No previous reports on its use in chemically leavened quick breads have been published. Some work has been reported, however, on the incorporation of field pea products in baked goods such as yeast breads (Repetsky and Klein 1981), biscuits (McWatters 1980), and cookies (McWatters 1978).

The purpose of this study was to determine the effects of substituting three different levels (5, 10, and 15%) of yellow field pea or defatted soy flour for wheat flour in a chemically leavened quick bread. Changes in physical properties of batters (linespread apparent viscosity) and baked breads (volume, compressibility, and crumb color), and sensory qualities (external and internal characteristics) of finished products were studied.

MATERIALS AND METHODS

Baker's Nutrisoy, a defatted soy flour (Archer Daniels Midland Company, Decatur, IL) and Dupro 300, an all-purpose yellow field pea flour (Dumas Seed Company, Edina, MN) were substituted for wheat flour in a quick bread formula (Table I) on a weight basis at 5, 10, and 15% levels, with 100% wheat flour serving as the control. The muffin method of mixing was used to prepare the batter. A Kitchen Aid mixer (model 4-C) was used to mix blended liquid ingredients with dry ingredients at speed 1 for 15 sec. A 500-g portion of batter was measured into each of two greased loaf pans (19 × 9.2 × 5.7 cm). Loaves were baked for 55 min in a rotary hearth oven preheated to 177°C. Loaves were depanned 10 min after removal from the oven and cooled on a wire rack for 1 hr. Loaves were then wrapped in clear plastic wrap for 24 hr. One was used for sensory evaluation and the other for objective measurements (volume, compressibility, and crumb color).

A modification of the linespread test by Grawemeyer (1943) was used to measure the apparent viscosity (consistency) of batters by measuring flow. Readings were taken at four points on the concentric circles (⅛-in. units) at 60-sec intervals.

Volume of the quick breads was determined by a modification of the rapeseed displacement procedure described by Cathcart and Cole (1930). Loaf volume was calculated from the weight of rapeseeds displaced by the loaf and from the weight of a known volume of rapeseeds.

The Gardner color difference meter (model C-4) was used to measure color of the bread crumb. The ends of the loaf were cut off. Three alternate 1-in. (2.54 cm) slices were used for color measurement and the other three for compressibility determination. A standard white plate (CG-6625) was used with reference values of L = 92, a = −1.0, b = +1.7.

A Precision Penetrometer, fitted with a flat disk and an added 150-g weight, was used to measure compressibility (crumb texture)

TABLE I
Formulas for Chemically Leavened Quick Breads Substituted with Soy or Pea Flour

Ingredients	Control 100% Wheat (g)	Substitution Level (g) 5%	10%	15%
Wheat flour[a]	576	547	518	490
Other flour[b]	···	29	58	86
Sugar	250	250	250	250
Baking powder[c]	24	24	24	24
Salt	12	12	12	12
Eggs	96	96	96	96
Milk	604	604	604	604
Vegetable oil[d]	112	112	112	112

[a] Gold Medal all-purpose flour.
[b] Dupro 300 pea flour, Dumas Seed Co., Edina, MN or Baker's Nutrisoy (Defatted), ADM Foods, Decatur, IL.
[c] Calumet (SAS) baking powder.
[d] Crisco oil.

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of the loaves. Two samples (1-in. diameter), one from the top and one from the bottom of each slice, were cut from the three alternate 1-in. slices. The degree of compression (in millimeters) of each sample was recorded after 30 sec.

Breads were evaluated for sensory characteristics by a semitrained panel of 8–11 women of the Department of Foods and Nutrition at the University of Illinois, Urbana-Champaign. Individual booths with incandescent lighting were used, and three samples were evaluated per session. A score card with an unstructured scale with descriptive anchors was used in the evaluation of both external and internal characteristics of the samples. External characteristics evaluated were overall shape, crust color, thickness, and surface texture. Internal characteristics evaluated were crust and grain texture, mouthfeel, crumb color and distribution, and flavor (odor and taste). Each characteristic was evaluated by making a vertical mark along a horizontal line 155 mm long with anchor points 1.3 mm from each end. Each anchor point was labeled with a descriptive word as shown in Table II. A ruler was placed over each line, and a numerical value was assigned to each rating (0–155).

TABLE II
Sensory Characteristics, Scale Anchors, and Acceptable Range for Each Characteristic

Characteristics	Scale Anchors	Acceptable Range[a]
External		
Shape	flat: peaked	63–93 (77.5)
Crust		
Color	pale: dark brown	63–93 (77.5)
Thickness	thick: thin	63–93 (77.5)
Surface texture	smooth: pebbled or rough	125–155
Internal		
Crust	gummy: tough	63–93 (77.5)
Grain		
Crumb texture	soggy: dry	63–93 (77.5)
Tunnels	many: few	125–155
Air cells	few: numerous	125–155
Mouthfeel	cohesive: crumbly	125–155
Color of crumb	dark: creamy white	125–155
Color distribution	uneven or streaked: uniform	125–155
Flavor		
Odor	strong: pleasing or natural	125–155
Taste		
Aftertaste	great: none	125–155
Offtaste	great: none	125–155
Taste desirability	undesirable: desirable	125–155

[a] The acceptable range is the third of the scale closest to the optimum score. Optimum score is given in parentheses when it differs from 155.

TABLE III
Linespread Consistency, Loaf Volume, and Gardner Color Difference Meter Readings of Quick Breads Made with Different Levels of Soy or Pea Flour[a]

	Linespread Consistency[b] (1/8 in. units)	Volume[b] (ml)	Gardner Color Meter Readings[b] L	b(+)
Control	5.7 a	910.3 a	71.7 a	21.1 a
Soy				
5%	5.2 ab	941.9 b	71.0 ab	21.4 ab
10%	4.8 ab	932.0 a	69.3 bc	21.6 ab
15%	3.6 c	950.3 b	67.8 c	21.8 ab
Pea				
5%	5.9 ab	904.9 a	70.6 abc	22.1 b
10%	6.5 ad	901.5 a	69.5 bc	22.2 b
15%	6.9 d	894.4 a	68.7 c	23.3 c

[a] Values are means for four replications.
[b] F values indicated that means for linespread consistency, volume, and "b" values were significantly different at $P < 0.01$; L values were significantly different at $P < 0.05$. Least significant difference (5%) for linespread = 0.9; volume = 22.9; b = 0.9; L = 1.9.

The control and each treatment substitution were replicated four times. Three breads were baked on one day, in a completely randomized design. Analysis of variance (ANOVA) was calculated for each parameter. Least significant differences (LSD) were computed at the 5% level of significance when F values were significant at the 1 or 5% level.

RESULTS AND DISCUSSION

Objective Measurements

Significant differences due to substitution of soy or pea flour for wheat flour among some batters and breads in the objective measurements of linespread consistency, volume, L (darkness), and "b" (yellowness) crumb color values are listed in Table III.

Linespread Consistency. Linespread consistency was significantly different ($P < 0.01$) among batters. Control batter was less viscous than 15% soy flour batter, and within the soy flour group 15% soy flour batter spread significantly less than the 5 and 10% soy flour batters. This may have been due to the water-sorptive capacity of soy proteins (Finney et al 1960). Ranhotra and Loewe (1974) found an increase in water absorption in doughs containing defatted soy flour as the percentage of soy flour increased from 10 to 20%. Jeffers et al (1978) found a 1% increase in water absorption of doughs for each 5% soy flour added. In the present study, no adjustment was made to compensate for the water-holding ability of the soy flour.

The opposite effect occurred in batters containing pea flour. The control batter was more viscous and spread significantly less than the 15% pea flour batter, and the 5% pea flour batter was significantly more viscous than the 15% pea flour batter. This indicates that pea flour has relatively limited water-sorptive capacity, and is in agreement with Jeffers et al (1978), who found a 1.8% decrease in water absorption for each 5% addition of pea flour. However, Tripathi and Date (1975) found an increase in water absorption as the percentage of pea flour increased.

Volume

Loaf volume was significantly different ($P < 0.01$) among the breads. The volumes of 5 and 15% soy flour loaves were significantly greater than the control loaf. The volume of quick breads containing field pea flour progressively decreased as the percentage of pea flour increased, and were all less than the control loaf, although differences were not significant. All soy flour loaves were significantly greater in volume when compared to pea flour counterparts except for the 10% level. This may be due to increased batter viscosity and less air and leavening gas escaping from the thicker soy flour batter. However, other investigators (Howarter and Klein 1978) using full-fat soy flour in quick breads did not observe significant changes in loaf volume. Fleming and Sosulski (1977) and Jeffers et al (1978) observed significantly lower loaf volume in yeast-leavened bread made with defatted soy flour than in control loaves. In yeast breads the structure is dependent on development of gluten, whereas in quick breads the avoidance of gluten development is critical for good grain characteristics. Therefore, the dilution of gluten by addition of low functional property ingredients will affect yeast breads more than quick breads.

No significant difference was found in compressibility between control, soy, and field pea loaves, indicating that there was no observable effect of flour substitution on crumb texture of quick breads.

Gardner Color Difference Meter Readings for Quick Bread Crumb

The L values decreased significantly ($P < 0.05$) as the percentage of soy flour and pea flour increased. Five percent soy crumb had the highest L value (lightest crumb) whereas 15% soy crumb had the lowest L value (darkest crumb) of all breads with protein supplementation. No differences in lightness between the control and 5% substitution levels were observed. However, the control loaf crumb was significantly lighter than the 10 and 15% soy and pea flour loaves. Also, there were no significant differences within the pea flour group or between loaves containing identical amounts

of soy and pea flour. McWatters (1980) found that crumb color of biscuits made with field pea flour and field pea concentrate were significantly darker (lower L value) and yellower (higher "b" value) than control biscuits, but others (Repetsky and Klein 1981) found no significant differences in crumb L, "a," or "b" values in yeast leavened bread containing 2.5, 5.0, and 10% pea flour.

No significant differences in "a" (redness) values of the crumb were found. The soy flour crumbs were not significantly different in "b" (yellowness) values from the control loaf crumb. However, the pea flour loaves were significantly yellower ($P<0.01$) than the control loaf, and the 15% pea flour crumb had significantly higher "b" value than the other levels. Comparison between identical levels of soy and pea flour crumb showed only the 15% pea flour loaf significantly yellower than the 15% soy loaf. These findings are in general agreement with those of McWatters (1980) in biscuits.

Sensory Characteristics

There were no significant differences between control, soy, and field pea flour loaves for the following external and internal sensory characteristics: shape, crust thickness, surface texture, crust texture, crumb texture, tunnels, and mouthfeel. However, some significant differences were observed among control, soy and field pea loaves in crust color, air-cell number, crumb, and distribution of crumb color as shown in Table IV, and flavor scores, listed in Table V.

Crust Color. The control loaf crust color was significantly ($P<0.01$) lighter than those of all soy and pea flour loaves. As the percentage of soy flour increased, color scores increased. There were no significant differences among levels of pea flour. Comparison of crust color among loaves containing identical levels of soy and pea flour showed soy flour crusts significantly darker than pea flour crusts at the 10 and 15% level. Other investigators have also found that loaves made with soy flour (Howarter and Klein 1978, Jeffers et al 1978, Klein et al 1980) or field pea flours (Jeffers et al 1978, Repetsky and Klein 1981) were considerably darker than control loaves. Crust color is a result of the Maillard reaction between reducing sugars and proteins. In this case, an increase in protein content, especially the higher lysine, from either soy or field pea flour probably caused the darker crust color (Bertram 1953).

Air Cells. The relative air-cell number in the breads was significantly different ($P<0.01$). The 10 and 15% soy flour loaves contained significantly more air cells than the control, and the 15% soy flour loaves contained significantly more air cells than the 5% soy loaves.

In the pea flour loaves, the number of air cells decreased as the percentage of pea flour increased, with a sharp decrease in air-cell number at the 10% level. The 5% pea loaf contained significantly more air cells than the control, 10% pea, and 15% pea loaves. Comparison of air-cell number between loaves with identical levels of soy and pea flour showed that 10 and 15% soy loaves contained significantly more air cells than their pea flour counterparts. This might be related to better foaming capacity and stability of soy versus field pea protein.

Crumb Color. Crumb color of the control was significantly ($P<0.01$) lighter than that of breads made with all levels of soy and pea flour. Within the pea flour group, 15% pea flour crumb was significantly darker than its 5% counterpart. There was no significant difference, however, in crumb color among all levels of soy flour, and between loaves containing identical levels of soy and pea flour. This is in agreement with other investigators who found a decrease in color scores when soy flour (Klein et al 1980) or pea flour (McWatters 1980, Repetsky and Klein 1981, Sosulski and Fleming 1974) was substituted into a bread or biscuit recipe.

Crumb Color Distribution. The acceptable range of scores for this sensory characteristic was 125–155, indicating uniform color of the crumb. There was no significant difference in crumb color distribution between control and all levels of soy flour loaves, within all levels of soy and pea flour loaves, and between loaves with identical levels of soy and pea flour. Control crumb color distribution was significantly ($P<0.05$) more uniform than that of the 10 and 15% pea flour loaves. In the pea flour group, there was a decrease in score as the level of pea flour increased, indicating that the color was not uniform in pea flour breads at the higher levels. This may also be related to differences in distribution of air cells in the bread, since the bottom of the loaves was relatively dense.

Flavor. The taste panel scores for flavor include odor and taste (comprising aftertaste, and taste desirability) of the quick breads. There was no significant difference in odor of the breads between control and all levels of soy flour, and within all levels of soy flour. However, with all levels of pea flour, odor ratings were significantly ($P<0.01$) lower than for control loaves, and 10 and 15% pea flour loaves also were rated significantly lower than the 5% pea flour loaf. Comparing identical levels of soy and pea flour loaves showed that the soy loaves rated significantly higher than pea flour loaves for odor at each level.

The panelists commented on the "nutty" or "pea" odor in the 10 and 15% pea flour loaves. The trend of this data agrees with that of Sosulski and Fleming (1979), who found that breads made with 15% defatted soy flour and 15% field pea protein concentrate rated lower than the 100% whole wheat bread in aroma. Wheat scored higher than soy, which scored higher than field pea breads.

Taste. There was a significant ($P<0.01$) difference in aftertaste when control or soy flour loaves were compared to all levels of pea flour, with pea flour loaves having more aftertaste. No significant differences between control and all levels of soy flour were found. Comparison within the soy flour group showed no significant difference in aftertaste. However, 5% pea flour loaves had significantly less aftertaste than 10 and 15% pea flour loaves. Comparing identical levels of soy flour and pea flour indicated that the pea flour loaves rated significantly lower (greater aftertaste) than the soy flour loaves at each level.

Offtaste results were similar to those for aftertaste. All levels of

TABLE IV
Sensory Evaluation Scores for External and Internal Characteristics of Quick Bread Made with Different Levels of Soy or Pea Flour[a]

	Crust Color[b]	Air Cells[b]	Crumb Color[b]	Crumb Color Distribution[b]
Control	59.1 a	93.7 ab	114.0 a	122.0 a
Soy				
5%	82.7 bc	95.5 bc	100.6 b	119.7 ab
10%	96.7 cd	102.3 cd	93.3 bc	116.0 ab
15%	108.8 d	104.1 d	89.3 bcd	119.1 ab
Pea				
5%	81.4 b	101.7 cd	93.7 bc	112.1 ab
10%	80.0 b	86.7 a	86.3 cde	110.2 b
15%	90.2 bc	92.9 ab	80.5 de	109.8 b

[a] Values are means for four replications.
[b] F values indicated that means for crust color, air cells, and crumb color were significantly different at $P<0.01$; crumb color distribution values were significantly different at $P<0.05$. Least significant difference (5%) for crust color = 14.2; air cells = 8.0; crumb color = 11.9; crumb color distribution = 10.2.

TABLE V
Sensory Evaluation Scores for Flavor Characteristics for Quick Breads Made with Different Levels of Soy or Pea Flour[a]

		Taste		
	Odor[b]	Aftertaste[b]	Offtaste[b]	Desirability[b]
Control	122.5 a	116.7 a	120.7 a	115.3 a
Soy				
5%	121.7 a	121.3 a	123.8 a	116.3 a
10%	121.4 a	119.8 a	119.1 a	115.1 a
15%	116.0 a	108.7 a	108.9 a	101.6 ab
Pea				
5%	101.4 b	96.7 b	86.0 bc	87.4 bc
10%	83.0 c	79.1 c	73.0 cd	75.5 cd
15%	77.2 c	77.2 c	60.6 d	65.6 d

[a] Values are means for four replications.
[b] F values indicated that means for odor, aftertaste, offtaste, and desirability were significantly different at $P<0.01$. Least significant difference (5%) for odor = 11.8; aftertaste = 14.5; offtaste = 18.3; desirability = 17.3.

pea flour loaves had significantly ($P < 0.01$) more offtaste than control loaves, but there were no significant differences between control and all levels of soy flour. There was a significant difference within the pea flour group, with 15% pea flour bread having more offtaste than 5% pea flour bread. Similarly, comparing identical levels of soy and pea flour loaves showed that the pea flour loaves had significantly greater offtaste than their soy flour counterparts.

Control loaves were rated higher in taste desirability than all levels of pea flour, but there was no difference when compared to soy flour loaves. Comparison within the soy flour group showed no significant difference in taste desirability, whereas within the pea flour group taste desirability decreased when 5 and 15% loaves were compared. There was a significant ($P < 0.01$) difference in taste desirability at each level when loaves containing identical amounts of soy and pea flour were compared, with the soy always rated higher.

SUMMARY

The results of this study indicate that Nutrisoy, a defatted soy flour, could be successfully substituted for wheat flour in chemically leavened quick breads at levels up to 15%. Yellow field pea flour (Dupro 300) appeared to have more adverse effects than soy flour on both physical and sensory characteristics of the quick breads. A distinct "pea" odor and "nutty" taste was noted to increase with increasing levels of substitution. In a plain, mildly sweet, chemically leavened quick bread, use of pea flour would not produce a desirable product. In yeast breads, however, up to 10% pea flour can be used (Repetsky and Klein 1981). Addition of a flavoring or changing formulation or mix procedures for a quick bread would be needed to produce an acceptable product.

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