Rheological and Sensory Characteristics of Bread Flour and Whole Wheat Flour Doughs and Breads Containing Dry-Roasted Air-Classified Pinto and Navy Bean High-Protein Fractions[1]

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ABSTRACT

Dry-roasted navy and pinto bean cotyledons were ground and air classified. The high-protein (40–44%) fractions were used as a substitute for bread flour and whole wheat flour in dough and bread systems. Blends of bread or whole wheat flour/high-protein legume flour were prepared in the proportions 100:0, 90:10, 85:15, and 80:20. Water absorption, arrival, and dough development time increased while stability decreased for both bread flour and whole wheat flour farinograms. Treatments with 10 or 20 ppm potassium bromate and 0.5 or 1% sodium stearoyl-2-lactylate improved bread volume. Legume substitution tended to increase tenderness and reduce lightness of breads. Increasing levels of legume substitution significantly decreased many sensory parameters of white bread, but fewer significant differences were found for whole wheat breads.

Cereal Chem. 66(6):486–490

Protein inadequacies are a problem facing risk population groups of the world, particularly populations in developing countries where diets consist mainly of cereals. Even in the United States where governmental programs supply food and/or food stamps, there are populations of low-income expectant mothers and children with inadequate diets. Increased utilization of high-protein legumes (*Phaseolus vulgaris*) in basic food, such as bread, is a method of dealing with food shortages on a world scale.

Dry-roasting and air classification has produced legume flours high in protein and low in antinutritional factors (Aguilera et al 1982a,b). These flours have excellent nitrogen solubility indexes, light color, and bland flavor, thus overcoming many previous drawbacks to legume flour utilization. Decline in dry bean consumption in the United States has prompted investigations into the use of bean ingredients in food. Dry bean white flours and/or high-protein flours produced by dry-roasting followed by air classification have been successfully used in a number of products produced for soft wheat blends (Dryer et al 1982; Spink et al 1984; Zabik et al 1983, 1985).

Several studies have demonstrated that the amount of legume flour needed to produce the desired level of protein fortification results in difficult handling and manipulation of the dough, decreased loaf volume, and deleterious changes in crumb grain and texture (McConnell et al 1974; D'Appolonia 1977; Knorr and Betschart 1978, 1981; Deshpande et al 1983). Knorr and Betschart (1978) proposed that reduced volume resulted from detection of gliadin and glutenin and interference with gluten formation by the presence of legume proteins. Fleming and Sosulski (1978) reported that concentrated plant proteins disrupt the well-defined protein-starch complex characteristic of wheat flour bread. However, the addition of dough conditioners, dough strengtheners, and surfactants was found to counteract some of these deleterious effects (Tsen and Hoover 1971, Tenny 1978).

The present study investigated the use of four composite blends of wheat flour/legume flour (100:0, 90:10, 85:15, 80:20) using all combinations of both bread and whole wheat flours as the wheat flour components and both high-protein navy and high-protein pinto flours as the legume components. Each of these 16 combinations was then prepared with two levels of a dough strengthener (potassium bromate) and two levels of a dough conditioner (sodium stearoyl-2-lactylate) to improve bread characteristics.

[1]Michigan Agricultural Experiment Station Journal Article 12929

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MATERIALS AND METHODS

Mature pinto and navy beans (*Phaseolus vulgaris*) were obtained in Michigan and shipped to the Food Protein Research and Development Center of Texas A&M University where they were dry-roasted and then air classified at Alpine Corporation according to the methods outlined by Aguilera et al (1982a,b). Chemical analyses of these flours showed the high-protein navy bean flour to contain 7.5% moisture, and on a dry weight basis 41.6% protein, 4.9% ash, 3.7% enzyme neutral detergent fiber, and a nitrogen solubility index of 41.0 (Uebersax and Zabik 1986). The high-protein pinto flour contained 6.3% moisture, and on a dry weight basis 42.5% protein, 4.9% ash, 5.1% enzyme neutral detergent fiber, and a nitrogen solubility index of 49.4. All other ingredients used in dough or bread formation were obtained commercially.

Farinograms were obtained according to AACC method 54-21B (AACC 1983). Farinograms were obtained for doughs without conditioners or strengtheners.

Breads were baked according to the AACC 10-10A basic straight dough method. Mixing time and water content were determined from the farinograph studies and unpublished preliminary testing. Fermentation and proofing time was based on these studies. The effect of 0, 10, and 20 ppm potassium bromate $KBrO_3$ (dough strengthener) and 0, 0.5, 1.0% sodium stearoyl-2-lactylate (SSL) (dough conditioner) alone and in combination were investigated. The formula used for optimum bread quality included 100% flour or flour/protein concentrate blends, 6% sugar, 5% active dry yeast, 4% nonfat dry milk, 3% hydrogenated vegetable shortening, 1.5% salt, 0.3% malt, 40 ppm ascorbate, 0, 10, or 20 ppm $KBrO_3$, 0, 0.5, or 1% SSL, and water as determined by the farinograph. Water levels for variables made with bread flour were 61.4, 79.0, 85.0, and 98.0 ml, respectively for 100:0, 90:10, 85:15, and 80:20 flour/navy or pinto bean protein concentrate blends. For whole wheat flour the water content was 67.7, 84.0, 92.0, and 99.0 ml, respectively.

Doughs were mixed using a slow speed. The mixer bowl was covered with a damp cloth to prevent drying of the bowl sides and surface evaporation. Doughs were fermented and proofed at 31.0 ± 1.0°C. For bread flour systems, fermentation times were adjusted to 90, 80, 75, and 70 min, respectively, for 100:0, 90:10, 85:15, and 80:20 flour/navy or pinto bean protein concentrates. Fermentation times in the whole wheat system were 90, 75, 70, and 65 min, respectively. All doughs were baked in a National Manufacturer rotary oven for 24 min at 218°C. After cooling 1 hr, loaf volume was determined by rapeseed displacement. Interior color of 1-cm slices was determined using a Hunter Color Difference Meter model D-25-2 with a yellow tile ($L = 78.5$, $a_L = -3.2$, $b_L = 23.4$). Bread tenderness was determined using a Food Technology Corporation Texturecorder (model TR5) equipped with a standard shear compression cell. A 3,000-lb transducer, operating at a range 1/30 and a 30-sec down stroke, was used throughout the testing.

Eight graduate student and faculty judges who regularly serve on sensory panels were trained to evaluate the breads for the characteristics given in Table I. Training consisted of participation in a minimum of three preliminary panels to allow the judge to become familiar with the score card and to insure the judges ability to replicate evaluations. Taste panels were conducted in individual booths equipped with daylight fluorescent lighting.

Samples for sensory evaluation were wrapped in plastic wrap, coded with a two-digit random number, placed in zip-lock bags, and refrozen at the time of objective evaluations. Presentation of the bread samples was completely randomized. Four samples that had been thawed to room temperature were presented to taste panelists during each panel session.

Three replications of all variables were prepared. Data were analyzed for variance using a three-factor factorial that included protein level, oxidant level, and dough conditioner level as well as all interactions. Duncan's multiple range test (Duncan 1957) was used to determine significant differences among means.

RESULTS AND DISCUSSION

Farinograph studies showed that the incorporation of either navy or pinto protein flours into bread or whole wheat flour systems increased arrival time, dough development time, and water absorption and greatly reduced dough stability. The effect of the pinto protein concentrate (PPC) and these parameters is illustrated in Figure 1. Similar characteristics were noted when navy bean protein (NPC) was used in either the bread or whole wheat flour systems. This is in agreement with results of previous studies using wheat flour blends (D'Appolonia 1977, Deshpande et al 1983, Fleming and Sosulski 1977, Zabik et al 1983).

When the volume of water, mixing time, and fermentation time in the dough formulation were optimized, breads of similar volume to the control bread were obtained for the bread (Fig. 2) and whole wheat flour (Fig. 3) systems. The incorporation of 0.5 and 1.5% SSL and 10 or 20 ppm $KBrO_3$ improved volume for most variables. This agrees with reports of previous researchers (Tsen and Hoover 1971, Tenney 1978). The ideal combination of SSL

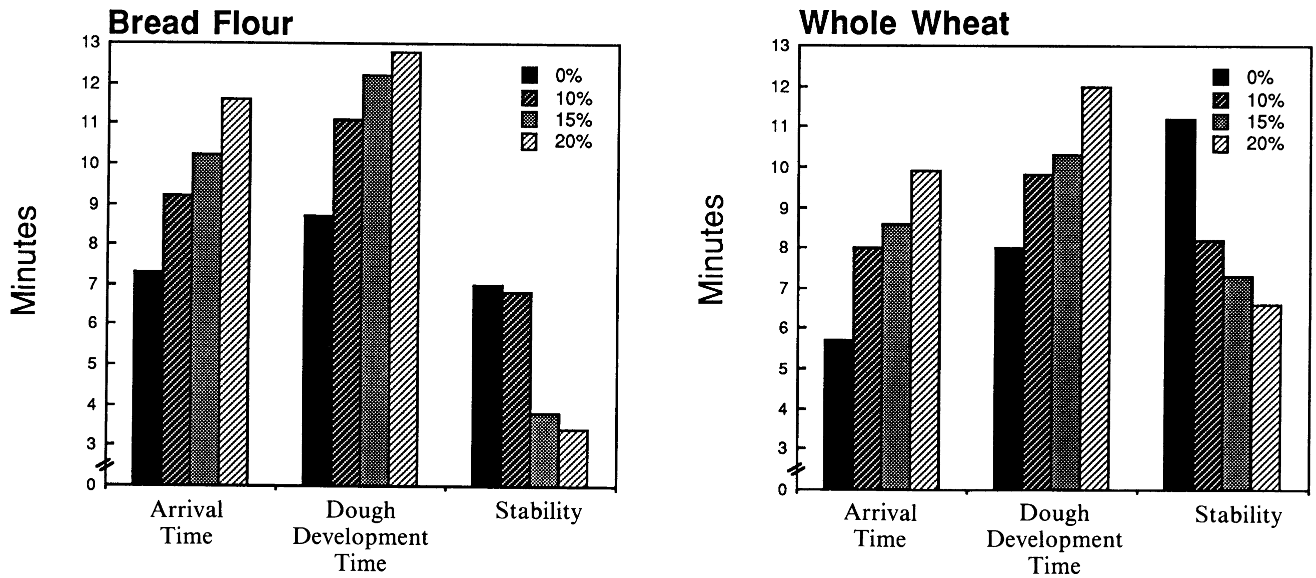

Fig. 1. The effect of pinto protein concentrate substitution on farinograph parameters using bread and whole wheat flour/concentrate blends.

TABLE I
Descriptors Used for Sensory Evaluation of Bread

Score	Crust Color	Crust Character	Crumb Color	Grain Texture	Grain Tenderness	Flavor
7	Rich golden brown, even	Soft tender breaks easily	Creamish white bright	Fine cells evenly distributed	Tender, soft moist	Excellent
6	Rich golden brown, sl.[a] uneven	Mod.[a] soft, mod. tender, mod. thick	Cream white	Mostly fine cells with a few coarse fairly even	Tender Soft and sl. moist	Very good
5	Brown	Sl. soft, mod. tender, mod. thick	Creamish white moderate bright	Sl. uneven cell structure, mod. coarse/fine	Sl. tender Sl. soft, moist	Good
4	Very slightly dark brown	Mod. tough, mod. thick, mod. rubbery	Deep cream white dull	Coarse and fine cells, thick and thin walls	Sl. tough and moist	Fair
3	Sl. dark brown	Sl. tough, mod. thick, sl. rubbery	Sl. greyish	Mod. coarse cells, thick walls	Sl. tough and dry	Sl. off flavor
2	Dark brown	Sl. rubbery tough, thick	Grey	Coarse cell structure uneven large holes	Tough, gummy, rubbery	Off flavor
1	Very dark brown	Tough, rubbery, thick	Dark and greyish	Compact, thick undistinguishable air cells	Tough and dry	Very poor Distinct off flavor

[a] Sl = slightly; mod = moderately.

and $KBrO_3$ varied depending on the amount of substitution with legume protein. Generally, as the amount of protein substitution increased, the amount of required dough strengthener (oxidant) increased. These findings are also related to lightness values for white bread systems as illustrated in Figure 4. As the volume increased and the crumb structure improved, the lightness of the bread improved. For most variables, incorporation of 20 ppm $KBrO_3$ in the bread formulation produced the lightest bread. All breads with PPC were slightly darker than those prepared with NPC. Because of the dark color of the whole wheat bread, incorporation of either PPC or NPC did not affect the color of whole wheat/bean flour breads. Lightness values ranged from 49.0 to 51.3.

Breads containing either NPC or PPC generally were more tender than the control (Fig. 5). Substitution of legume flour for bread or whole wheat flour dilutes the gluten (Knorr and Betschart 1978) and may interfere with the formation of a well-defined protein-starch complex (Fleming and Sosulski 1978). Use of 0.5% SSL further increased crumb tenderness. This is in agreement with the report of Tenney (1978). Similar findings for tenderness were found for whole wheat bread systems.

Sensory scores ranged from 4.7 to 5.9 for control breads (Table II). Low levels of protein concentrate substitution (i.e., 10%) reduced the scores to approximately 4 or a fair range. These reductions were significant for crust color and crumb color with both pinto and navy bean, and for flavor with substitution of PPC. Increasing the substitution to the 15% level caused a further reduction in most sensory scores; however, tenderness of breads with either PPC or NPC and crust character and grain texture of bread with NPC were not significantly affected. Increasing the level of substitution to 20% further adversely affected many sensory scores. Other sensory scores for whole wheat breads were similar.

Table III presents the effect of incorporation of potassium bromate and sodium SSL on the sensory characteristics of the white bread. Similar findings also occurred for whole wheat

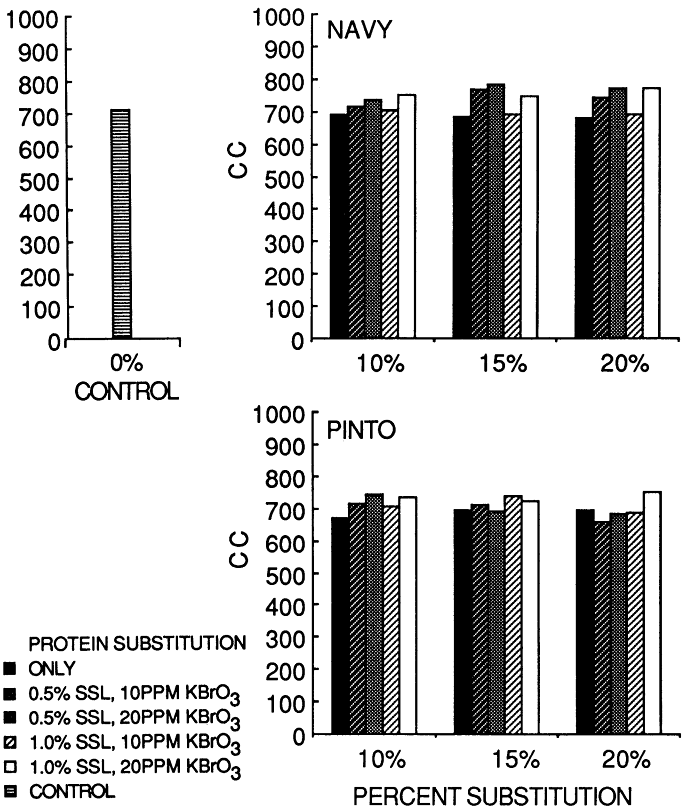

Fig. 2. The effect of substituting 0–20% navy or pinto protein concentrate on volume of bread flour products prepared with 0, 0.5, or 1.0% sodium stearoyl-2-lactylate and 0, 10, or 20 ppm $KBrO_3$.

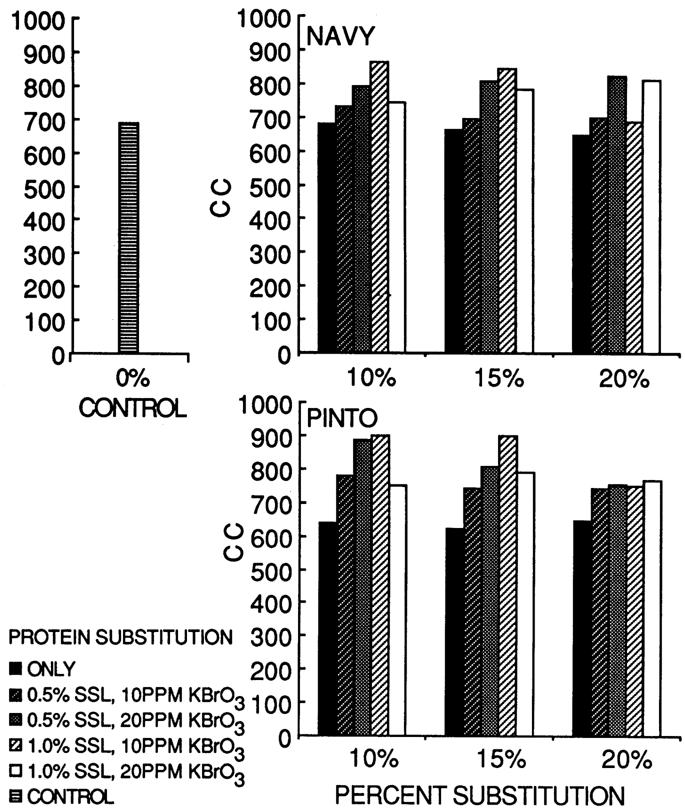

Fig. 3. The effect of substituting 0–20% navy or pinto protein concentrate on volume of whole wheat breads prepared with 0, 0.5, or 1.0% sodium stearoyl-2-lactylate and 0, 10, or 20 ppm $KBrO_3$.

TABLE II
Means[a] and Standard Deviations of Sensory Evaluation[b] of White Breads Containing 0–20% Pinto (PPC) and Navy (NPC) Bean Protein Concentrate for Flour

Substitution Level (%)	Crust Color		Crust Character		Crumb Color		Grain Texture		Tenderness		Flavor	
	PPC	NPC	PPC	NPC	PPC	NPC	PPC	NPC	PPC	NPC	PPC	NPC
Control (0)	5.4 a ±0.4	5.4 a ±0.4	4.7 a ±0.5	4.7 a ±0.5	5.9 a ±0.1	5.9 a ±0.1	5.4 a ±0.5	5.4 a ±0.5	5.3 a ±0.3	5.3 a ±0.3	5.4 a ±0.2	5.4 a ±0.2
10	4.2 b ±0.4	4.6 b ±0.5	4.5 a ±0.5	4.3 a ±0.5	3.7 b ±0.1	4.7 b ±0.2	4.1 ab ±0.5	4.8 a ±0.6	5.2 a ±0.3	4.8 a ±0.4	3.9 b ±0.1	4.6 a ±0.0
15	2.7 c ±0.4	4.7 b ±0.5	2.7 b ±0.4	4.4 a ±0.2	2.7 c ±0.2	4.4 c ±0.5	3.7 bc ±0.3	4.8 a ±0.2	5.2 a ±0.4	4.1 a ±0.1	3.6 bc ±0.2	4.2 b ±0.0
20	2.1 c ±0.4	3.9 c ±0.3	3.1 b ±0.5	4.2 a ±0.1	2.7 c ±0.4	4.2 c ±0.1	3.2 c ±0.2	4.6 a ±0.3	4.5 b ±0.3	4.5 a ±0.3	3.5 c ±0.2	4.1 b ±0.1

[a] Average of three replications.
[b] Sensory descriptors defined in Table I.
[c] Data followed by the same letter are not significant, only different among levels of protein substitution of either PPC or NPC ($P = 0.05$; Duncan 1957).

breads. The addition of SSL and $KBrO_3$ had the greatest effect on breads containing 15 and 20% protein concentrate substitution. No one combination produced the greatest improvement in all characteristics. At the 20% level of substitution, most combinations improved crust color and crumb character. For breads containing PPC, this improvement was significant at $P \leq 0.05$, but only the scores for crust character were raised to values of greater than 4. Grain texture score of breads with 20% PPC concentrate were greater than 4 when 10 ppm $KBrO_3$ and 1% SSL were incorporated ($P \leq 0.05$). Tenderness of bread with 20% PPC scored significantly higher ($P \leq 0.05$) with high levels of SSL or with 20 ppm $KBrO_3$ and 0.5% SSL.

This study showed that breads with satisfactory volume, tenderness, and color can be prepared with increased protein quantity and quality. Sensory scores were adversely affected with greater than 10% substitution of legume protein concentrate, although incorporation of $KBrO_3$ and SSL improved many of these attributes. Additional optimization of the baking process

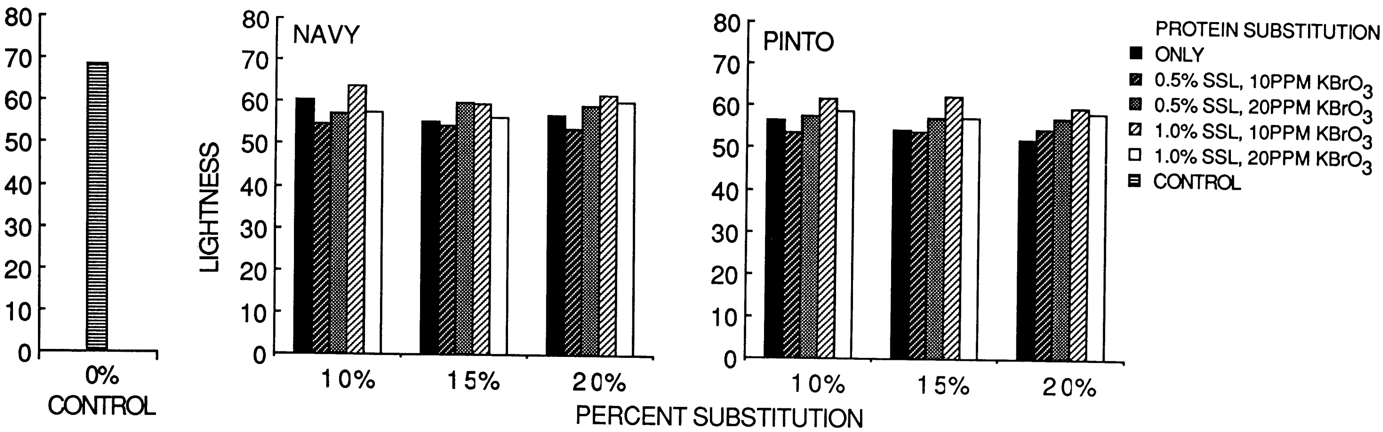

Fig. 4. The effect of substituting 0–20% navy or pinto protein concentrate on lightness of bread flour products prepared with 0, 0.5, or 1.0% sodium stearoyl-2-lactylate and 0, 10, or 20 ppm $KBrO_3$.

TABLE III
Influence of Potassium Bromate and Sodium Stearoyl-2-Lactylate (SSL) on Sensory Evaluation[a] of Bread with 10–20% Pinto (PPC) or Navy (NPC) Protein Concentrate Substituted for Flour

$KBrO_3$ (ppm)	SSL (%)	Crust Color PPC	Crust Color NPC	Crust Character PPC	Crust Character NPC	Crumb Color PPC	Crumb Color NPC	Grain Texture PPC	Grain Texture NPC	Tenderness PPC	Tenderness NPC	Flavor PPC	Flavor NPC
						10% Level of Substitution[b]							
0	0	4.2 ab ±0.4	4.6 ab ±0.5	4.5 a ±0.5	4.3 d ±0.5	3.7 b ±0.1	4.7 a ±0.2	4.1 a ±0.5	4.8 a ±0.6	5.2 a ±0.3	4.8 b ±0.4	3.9 a ±0.1	4.6 a ±0.0
10	0.5	4.4 ab ±0.6	4.3 bc ±0.3	4.4 a ±0.2	4.2 a ±0.7	3.5 b ±0.1	3.7 b ±0.2	3.9 a ±0.3	3.9 a ±0.4	4.9 a ±0.3	5.7 a ±0.2	4.5 b ±0.2	4.3 a ±0.4
10	1	3.0 c ±0.5	3.8 c ±0.2	4.4 a ±0.2	3.6 a ±0.3	4.3 a ±0.2	4.5 a ±0.3	3.9 a ±0.4	3.8 a ±0.4	4.9 a ±0.2	4.9 b ±0.3	4.6 b ±0.3	4.6 a ±0.2
20	0.5	4.0 bc ±0.6	5.2 a ±0.5	4.4 a ±0.3	3.6 a ±0.3	3.7 b ±0.1	3.6 b ±0.2	4.0 a ±0.3	4.5 a ±0.7	4.8 a ±0.6	5.0 b ±0.5	4.8 b ±0.3	4.4 a ±0.3
20	1.0	5.1 a ±0.4	4.7 ab ±0.4	4.1 a ±0.1	3.7 a ±0.5	4.2 a ±0.2	3.7 b ±0.1	5.0 a ±0.6	4.8 a ±0.2	4.9 a ±0.2	4.7 b ±0.3	4.6 b ±0.2	4.3 a ±0.1
						15% Level of Substitution							
0	0	2.7 g ±0.4	4.7 d ±0.5	2.7 f ±0.4	4.4 de ±0.2	2.7 f ±0.2	4.4 e ±0.5	3.7 d ±0.3	4.8 d ±0.2	5.2 d ±0.4	4.1 e ±0.1	3.6 f ±0.2	4.2 e ±0.0
10	0.5	4.9 d ±0.6	4.7 d ±0.5	6.2 d ±0.2	5.2 d ±0.4	3.1 e ±0.3	3.7 f ±0.1	3.5 d ±0.5	4.2 de ±0.2	4.6 d ±0.4	4.6 e ±0.2	4.1 e ±0.1	4.3 e ±0.2
10	1	3.3 fg ±0.2	3.8 e ±0.5	3.9 e ±0.3	4.8 d ±0.2	4.0 d ±0.2	4.9 d ±0.1	4.1 d ±0.7	3.3 f ±0.2	4.8 d ±0.5	4.9 de ±0.4	4.7 d ±0.2	4.9 d ±0.3
20	0.5	3.7 ef ±0.3	4.3 de ±0.6	3.9 e ±0.0	3.8 e ±0.2	3.5 d ±0.1	3.7 f ±0.2	4.4 d ±0.6	4.7 d ±0.2	5.3 d ±0.5	5.4 d ±0.3	4.3 e ±0.2	5.0 d ±0.0
20	1	4.2 de ±0.5	4.5 de ±0.8	3.6 e ±0.2	4.5 d ±0.6	3.2 e ±0.2	3.8 f ±0.2	3.6 d ±0.2	3.6 ef ±0.6	4.5 d ±0.3	4.8 e ±0.2	4.3 e ±0.2	4.3 e ±0.2
						20% Level of Substitution							
0	0	2.1 i ±0.4	3.9 h ±0.3	3.1 i ±0.5	4.2 h ±0.1	2.7 j ±0.4	4.2 h ±0.1	3.2 i ±0.2	4.6 h ±0.3	4.5 ij ±0.3	4.5 h ±0.3	3.5 j ±0.2	4.1 i ±0.1
10	0.5	2.1 i ±0.0	4.4 h ±0.9	4.3 h ±0.2	5.0 h ±1.2	2.9 j ±0.5	3.7 h ±0.2	2.8 j ±0.6	3.9 h ±0.3	4.4 j ±0.1	4.8 h ±0.4	3.6 ij ±0.2	4.2 i ±0.0
10	1	3.3 h ±0.2	3.2 h ±0.8	4.6 h ±0.3	4.2 h ±0.6	4.4 h ±0.4	3.8 h ±0.2	4.1 h ±0.4	4.2 h ±0.3	5.0 hi ±0.5	4.8 h ±0.2	4.6 h ±0.1	4.5 h ±0.2
20	0.5	3.6 h ±0.4	3.8 h ±0.5	4.1 h ±0.2	3.8 h ±0.6	3.1 i ±0.2	3.9 h ±0.5	3.9 hi ±0.6	4.7 h ±0.5	5.1 h ±0.2	5.2 h ±0.2	4.1 h ±0.2	4.5 h ±0.2
20	1	3.3 h ±0.2	3.9 h ±0.9	4.0 h ±0.4	4.1 h ±0.8	3.4 i ±0.8	3.7 h ±0.2	4.2 h ±0.2	3.9 h ±1.1	4.9 hij ±0.2	5.2 h ±0.3	3.9 hi ±0.2	4.1 i ±0.0

[a] Mean ± standard deviation for 3 replications. Sensory descriptors defined in Table I.
[b] Data followed by the same letter for one protein substitution level with one protein concentrate, i.e., either PPC or NPC, are not significantly affected by combination of SSL and $KBrO_3$ ($P = 0.05$, Duncan 1957).

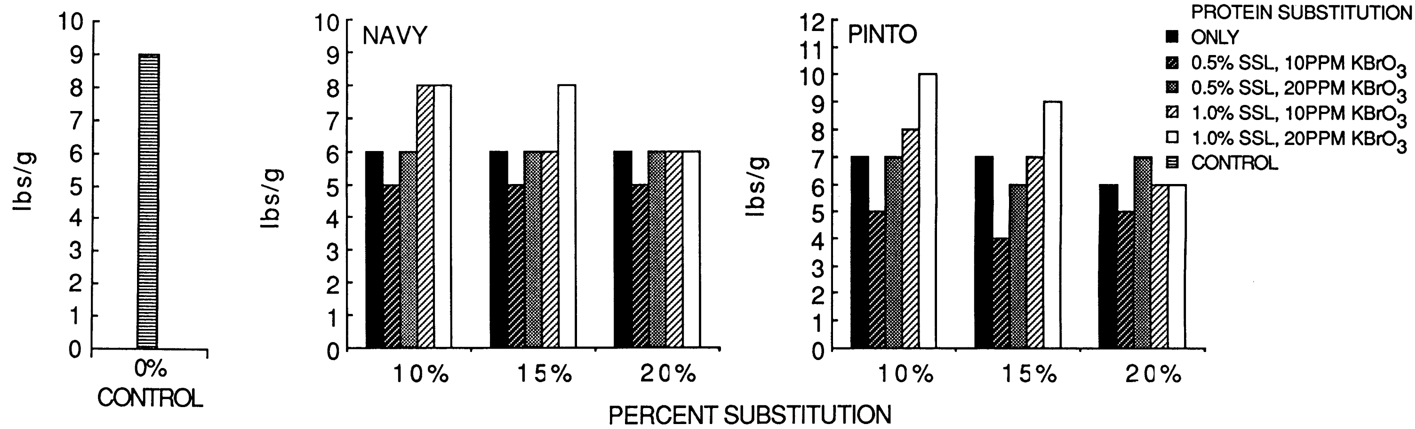

Fig. 5. The effect of substituting 0–20% navy or pinto protein concentrate on the tenderness of bread flour products prepared with 0, 0.5, or 1.0% sodium stearoyl-2-lactylate and 0, 10, or 20 ppm $KBr)_3$.

and level of oxidant and dough conditioner could further increase product quality. Wheat flour/bean flour breads may become an acceptable product to help alleviate protein deficiency in developing nations.

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[Received January 13, 1989. Accepted June 15, 1989.]