Counteracting the Deleterious Effects of Fiber in Breadmaking[1]

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ABSTRACT

Blends of wheat flour and wheat, corn, or soybean bran or coconut residue were baked into bread. The deleterious effects of up to 15 parts of wheat bran per 85 parts of wheat flour could be largely counteracted with the addition of vital gluten and one of several surfactants alone or in combination with shortening. Surfactants included diacetyl tartaric acid esters (DAT), ethoxylated monoglycerides (EMG), lecithin, sucrose monopalmitate (SMP), and sodium stearoyl-2-lactylate. In the absence of shortening, 1 g each of DAT, EMG, or SMP per 100 g of mixture materially increased loaf volume beyond the level produced by 3 g of shortening. In the presence of 3 g of shortening per 100 g of mixture, adding 0.5 g of DAT, EMG, lecithin, SMP, or sodium stearoyl-2-lactylate produced only small improvements above the levels produced when shortening alone was added.

The nutritional benefits of incorporating fiber into baked products have been the subject of numerous investigations. Insofar as effects on functional properties (in breadmaking) are concerned, three approaches have been used: 1) production of fiber-enriched bread that resembles conventional bread as much as possible (Dubois 1978; Pomeranz 1977a, 1977b; Pomeranz et al 1977), 2) production of bread that differs substantially in overall characteristics (loaf volume, crumb grain, etc.) from conventional bread and should be considered a specialty product, and 3) production of fiber-enriched extrusion types of products (Seiter and Seibel 1978). High-fiber bread containing brewer's spent grain was reported by Prentice and D'Appolonia (1977).

We report on measures that can be used to produce the conventional type of bread in which up to 15% of the white wheat flour is replaced by fiber-rich materials.

MATERIALS AND METHODS

A composite (CS-77) of straight-grade flours (average 73% extraction), milled on a Miag Multomat from hard winter wheat cultivars harvested in 1977 at several locations throughout the Great Plains of the United States, was used in the study. It had a protein content of 12.9% (N × 5.7, 14% mb), good loaf volume potential, and medium mixing and oxidation requirements.

Four sources of fiber were used. AACC standard white wheat bran (WB) was ground on a Weber mill to pass through a 100-mesh screen. It had protein and ash contents (14% mb) of 14.5 and 4.66%, respectively. A soy bran flour (SB), supplied by Archer Daniels Midland Company, contained 12.2 and 3.67% protein and ash (14% mb), respectively. Typical granulation allowed 100% to pass through a U.S. 40-mesh sieve and 75% through a U.S. 100-mesh sieve. The same company supplied a corn bran flour (CB) that contained 6.4 and 0.86% protein and ash, respectively. Granulation allowed 75–90% to pass through a U.S. 100-mesh sieve. The fourth fiber was a coconut residue (CO) supplied by the University of San Carlos Talamban, Cebre City, Philippines. It contained 3.8 and 0.65% protein and ash, respectively, and had a fine, flaky consistency.

Moisture, protein, and ash were determined by AACC approved methods 44-15A, 46-11, and 08-01, respectively.

The baking procedure of Finney and Barmore (1943, 1945a, 1945b) and Finney (1945) for 100 g of flour (14% mb) was used, except that ascorbic acid (50 ppm) was used as an oxidizing agent and soy flour (Ardex 550) was used as a replacement for milk. The standard deviation for the average of duplicate loaf volumes was 20 cc.

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[2]Mention of firm names or trade products does not imply their endorsement or recommendation by the USDA over other firms or similar products not mentioned.

TABLE I
Characteristics of Bread Baked with Flour at 5-g, 10-g, and 15-g Replacement Levels of Four Fibers

Fiber and Replacement Weight (g)	Loaf Volume (cc)	Mixing Time (min)	Absorption (%)	Crumb Grain[a]	Color, ΔE[b] Interior	Color, ΔE[b] Exterior	Crumb Compressibility at 1 hr (g)	Crumb Compressibility at 3 days (g)
0	1,077	4⅜	67.0	S	···	···	81.3	255
White wheat bran								
5	985	4½	69.3	Q–S	2.00	1.13	87.8	243
10	923	4⅝	72.0	Q	4.91	0.54	82.7	250
15	880	4¾	75.0	Q–U	6.24	2.41	84.5	229
Corn bran								
5	978	4⅞	69.5	Q–S	1.46	1.13	78.9	256
10	903	5⅛	71.9	Q	4.64	1.30	90.6	237
15	858	5⅛	74.3	U	5.66	1.46	86.5	266
Soy bran								
5	993	4⅝	72.0	Q–S	2.03	1.18	81.1	220
10	905	5¼	77.5	Q	5.00	1.30	98.3	228
15	848	5½	82.3	UU	6.60	1.46	117.0	269
Coconut residue								
5	904	5⅞	70.0	Q–U	1.18	0.81	87.8	248
10	758	8	77.0	UU	2.20	1.71	112.0	261
15	671	10¾	84.4	UUU	2.33	0.81	176.0	368

[a]S = satisfactory, Q = questionable, U = unsatisfactory, evaluated visually.
[b]$\Delta E = \sqrt{(\Delta L^2) + (\Delta a^2) + (\Delta b^2)}$.

CS-77 flour was replaced with 3, 5, 7, 10, and 15 g of each of the fibers, giving 100-g blends, and baked into bread. The formulation, on percent flour basis, was flour, 85.0–100.0; fiber, 0.0–15.0; sugar, 6.0; salt, 1.5; shortening, 3.0; soy flour, 4.0; yeast, 3.5; malted barley, 0.25; ascorbic acid, 50 ppm; and water, as needed. Doughs were fermented for 2 hr (during which they were punched twice), molded, proofed, and baked for 24 min at 425° F. Only results of testing 5-g, 10-g, and 15-g bran levels are reported here.

Additionally, two blends containing WB were tested as mixtures with vital gluten. The first mixture (12.9% protein) consisted of 10 g of WB, 87.8 g of flour, and 2.2 g of vital gluten. The second (also 12.9% protein) consisted of 15 g of WB, 81.8 g of flour, and 3.2 g of vital gluten. These blends were baked with no added shortening (SH), with 3.0 g of SH, with 1.0 g of lecithin, sodium stearoyl-2-lactylate, sucrose monopalmitate (SMP), ethoxylated monoglyceride (EMG), or diacetyl tartaric acid esters of monoglycerides and diglycerides (DAT), and with a combination of 3.0 g of SH and 0.5 g of lecithin, sodium stearoyl-2-lactylate, SMP, EMG, or DAT.

Crumb compressibility was measured with a Bloom gelometer 1 hr and 3 days after baking. The weight required to depress the plunger (25 mm in diameter) 4 mm into the bread crumb, after the crust was removed, was taken as the compressibility measurement. Three-day measurements were made on bread crumb from loaves that had been sealed and stored in plastic at room temperature (about 25° C).

Crumb and crust (top) color were determined with a Hunterlab color difference meter. To standardize, we used Hunterlab Tile Standard No. 025-927 ($L = 93.7$; $a_L = -0.6$; $b_L = 1.8$). Bread color differences were calculated as total color differences:

$$\Delta E = \sqrt{(\Delta L^2) + (\Delta a^2) + (\Delta b^2)}$$

RESULTS

Loaf characteristics of the control flour alone and at three replacement levels (5, 10, and 15 g) of the four fiber sources are given in Table I. As the replacement level increased from 5 to 15 g, the decrease in loaf volume went from 92 to 197 cc for WB, from 99 to 219 cc for CB, from 84 to 229 cc for SB, and from 173 to 406 cc for CO. Theoretically (calculated from dilution of gluten proteins), the decrease was expected to go from 54 to 162 cc. The three bran samples were similar in their effects on loaf volume changes. The CO was markedly more detrimental than any of the other fiber materials. An increase in fiber level was accompanied by an increase in mixing time. WB had the least effect and CO the greatest.

SB and CO increased dough absorption the most. The calculated water absorption of CO increased from 126% at the 5-g level to 183% at the 15-g level. WB showed a slight increase as level increased, whereas CB and SB showed no level-dependent change. The brans affected crumb grains little at the 5-g level. As bran level increased, crumb grains became questionable to unsatisfactory, WB causing the least effect. Bread containing CO was undesirable, having poor loaf appearance and very poor crumb grain.

Crumb color increased as bran level increased. Interior color changed more than exterior (top crust), becoming darker as fiber level increased. CO changed loaf color only slightly but did impart an undesirable gray cast. The darkened interior colors of the bran loaves were not necessarily undesirable and were similar to those of light rye or whole wheat breads.

Crumb compressibility of all the loaves except those made with 15 g of SB and with 10 and 15 g of CO varied little at hour 1. The day-3 results were inconclusive except that the compressibility of loaves made with 15 g of CO was very high.

Overall, detrimental effects of WB addition were smaller than

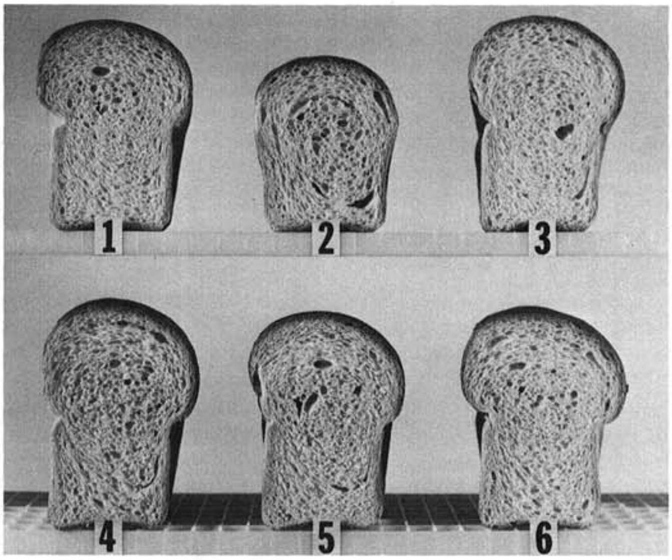

Fig. 1. Bread baked from a blend of 85 g of wheat flour and 15 g of wheat bran plus: **1,** 3 g of shortening; **2,** no additions; **3,** 1 g of ethoxylated monoglyceride; **4,** 1 g of sucrose monopalmitate; **5,** 1 g of sodium stearoyl-2-lactylate; **6,** 1 g of diacetyl tartaric acid esters of monoglycerides and diglycerides.

TABLE II
Characteristics of Bread Baked from Blends of 87.8 g of Flour, 2.2 g of Vital Gluten, and 10 g of Wheat Bran With and Without Improvers

Improvers[a]	Loaf Volume (cc)	Crumb Grain[b]	Crumb Compressibility at 1 hr	3 days
None	740	U	125	327
Shortening (3.0 g)	974	Q–S	72	227
Surfactant (1.0 g)				
LEC	987	Q–S	67	134
SSL	939	Q–S	85	168
SMP	1,032	Q–S	57	132
EMG	1,022	S	60	150
DAT	1,030	S	67	160
Shortening (3.0 g) and surfactant (0.5 g)				
LEC	994	Q	86	194
SSL	971	Q–S	80	166
SMP	1,015	Q–S	66	146
EMG	987	Q–S	67	220
DAT	1,017	Q–S	73	172

[a]LEC = lecithin, SSL = sodium stearoyl-2-lactylate, SMP = sucrose monopalmitate, EMG = ethoxylated monoglycerides, DAT = diacetyl tartaric acid esters of monoglycerides and diglycerides.
[b]Visually evaluated: S = satisfactory, Q = questionable, U = unsatisfactory.

TABLE III
Characteristics of Bread Baked from Blends of 81.8 g of Flour, 3.2 g of Vital Gluten, and 15 g of Wheat Bran With and Without Improvers

Improvers[a]	Loaf Volume (cc)	Crumb Grain[b]	Crumb Compressibility at 1 hr	3 days
None	699	UU	142	412
Shortening (3.0 g)	934	Q–U	86	206
Surfactant (1.0 g)				
LEC	932	Q	81	226
SSL	915	Q–S	83	166
SMP	1,024	Q–S	60	123
EMG	992	S	69	168
DAT	993	S	69	147
Shortening (3.0 g) and surfactant (0.5 g)				
LEC	945	Q	81	206
SSL	950	Q	86	148
SMP	1,005	Q–S	65	152
EMG	965	Q–S	71	155
DAT	983	Q	77	170

[a]LEC = lecithin, SSL = sodium stearoyl-2-lactylate, SMP = sucrose monopalmitate, EMG = ethoxylated monoglycerides, DAT = diacetyl tartaric acid esters of monoglycerides and diglycerides.
[b]Visually evaluated: S = satisfactory, Q = questionable, U = unsatisfactory.

those of the other fiber materials. Consequently, all subsequent tests on counteracting the adverse effects of fiber material were made with WB, the most "natural" additive. To reverse the effects of fiber on loaf volume, crumb grain, and freshness retention, vital gluten was mixed with flour and WB, and the mixtures with and without various combinations of shortening and several surfactants were used to bake bread (Tables II and III, and Fig. 1). The combinations of shortening and surfactant were studied because in previous studies on wheat and soy flour mixes, bread quality was improved more when SH and surfactants were used together than when used individually.[3]

The addition of either SH or a surfactant to the wheat flour-WB blends mixed with vital gluten substantially increased loaf volume. The increases in loaf volume were accompanied by improvements in crumb grain from questionable or unsatisfactory to questionable-satisfactory or satisfactory. Shortening and, especially, surfactants reduced the rate of bread staling (as measured by crumb compressibility on day 3).

The bread loaf volumes that would be expected when CS-77 is diluted with 10 and 15 parts of inert material are 969 and 915 cc, respectively. Dilution with 10 and 15 parts of WB, however, gave 923 and 880 cc, respectively (Table I). The more than theoretical decrease in loaf volume was prevented by the addition of vital gluten and improvers. In no case did addition of vital gluten plus shortening and/or surfactant restore loaf volume and crumb grain to those of bread baked without fiber. Several surfactants were quite effective in minimizing loaf volume reduction and crumb grain impairment; the best were DAT, EMG, and SMP.

[3] Unpublished data.

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