Effect of Commercial Oat Bran on the Characteristics and Composition of Bread[1]

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Cereal Chem. 64(1):55–58

ABSTRACT

White wheat flour was substituted with 10 and 15% levels of commercial oat bran to determine the effects on dough properties and bread quality. Particle size of bran was also varied in the formula. Protein and dietary fiber analyses were conducted along with other assays to determine the efficacy of supplementation. Product acceptability was judged by sensory evaluation. Absorption requirements in oat bran doughs increased with increases in bran levels as well as with bran particle size reduction. The 10% blends (large and intermediate size bran) produced doughs of good stability. Both 10 and 15% bran blends increased dough mixing time slightly over the control. The inclusion of bromate in the formula improved loaf volume, grain, and texture of oat bran breads. Dietary fiber and protein increased significantly with bran supplementation. No improvement in discriminant computed protein efficiency ratio was noted. The 10% bran breads had better loaf volume, grain, and texture than 15% bran breads. A taste panel preferred 15% bran bread (large bran) and 10% bran bread (intermediate bran).

Nutritional supplementation of commonly consumed food products has become an effective means of alleviating the problems of malnutrition. Introduction of dietary supplements may encounter problems of acceptability when the supplements are alien to people's food habits. For supplementation programs to work, the form of supplementation should use ingredients already familiar or acceptable to the local population, make use of technology already in existence to be cost effective, and should ensure a final product similar in characteristics to the food product being improved.

The protein digestibility, amino acid composition, and protein efficiency ratio of oat protein have been investigated (McElroy et al 1949, Howe and Fox 1965, Graham et al 1972, Pomeranz 1973). The nutritive value of oats, their low cost, useful protein functionality, and desirable bland taste make oats a suitable supplement ingredient. The effects of oat bran supplementation on protein nutritional quality of bread have not been reported.

The hypocholesterolemic effects of oat bran in humans have been documented (Kirby et al 1981). The increasing demand for specialty breads (Mrdeza 1978) and the implications of dietary fiber in the prevention of atherosclerosis (Trowell 1972), diverticulosis (Painter and Burkitt 1971), colonic cancer (Burkitt 1971), and appendicitis (Walker et al 1973) have made high-fiber breads more popular in the western hemisphere. The role of wheat bran, oat hulls, and commercial celluloses in breadmaking was investigated (Pomeranz et al 1976), and the functionality of triticale bran in breadmaking and effects of bran-particle size have been reported (Lorenz 1976). The effect of incorporating 10 and 20% oat bran on breadbaking characteristics was investigated by D'Appolonia and Youngs (1978). However, the effects of bran particle size on characteristics of dough and breads and chemical composition of the product have not been investigated. This study was extended to determine the effect of bran particle size on dough and bread characteristics, and to analyze the effect of adding oat bran on chemical composition and protein nutritional quality of the bread.

MATERIALS AND METHODS

Two hundred pounds of 1981 standard hard red spring wheat (variety Waldron) were tempered to 15.5% moisture and milled in a 55-cwt pilot mill (Buhler-Miag Co., Minneapolis, MN) to yield flour. The flour was sifted and then blended to ensure homogenous distribution of particle sizes.

Ninety pounds of commercial oat bran was obtained from Quaker Oats Company (Chicago, IL). Three kilograms of the bran were passed twice through a bran duster (Buhler-Miag Co.) to remove adhering endosperm material. The weights of bran recovered and oat flour removed were noted. Particle size measurements were made on the flour-free bran using a set of U.S. Tyler sieves (nos. 30 and 40) and a Ro-Tap testing sieve shaker (U.S. Tyler Co.). Weights of material over the sieves and that of material passing through the no. 40 sieve were recorded. Oat bran overs from the no. 30 sieves were designated as large oat bran (large), bran from the no. 40 sieves was similarly designated intermediate size bran (med), and the throughs of the no. 40 sieve were designated small size bran (small).

Oat bran-wheat flour blends were made at the 10 and 15% levels of bran substitution using large, intermediate, and small size bran. Unsubstituted flour was used as control. The blends were labeled control, 10% large, 10% med, 10% small, 15% large, 15% med, 15% small. Each blend was thoroughly mixed in a cross-flow blender (Patterson-Kelley Co., Stroudsburg, PA) for 20 min to ensure uniform distribution of bran in the flour.

Moisture contents of control flour and the six blends were determined by AACC method 14-16 (1983). Physical dough properties of control flour and blends were determined with a farinograph by the constant flour weight procedure of AACC method 54-21 (1983).

A conventional straight-dough baking procedure was conducted using a 2-hr fermentation, a single punch, and a proofing temperature of 30°C. The baking formula used was as follows: flour 100 g, (other ingredients based on flour weight, % w/w) yeast 3.0, sugar 5.0, salt 2.0, shortening 3.0, nonfat dry milk 5.0, potassium bromate 10 and 15 parts per million (when used), and variable amounts of water (to give 14% moisture basis).

Dough was mixed in a 100–200 g National mixer (National Mfg. Co., Lincoln, NE). A metal spatula was used when necessary to scrape the sides of the bowl to form a cohesive mass of dough. Mixing time was judged by physical examination of dough. A single punch was administered at the 55th minute of fermentation. This was followed by a further 55-min proofing.

The bread was baked at 230°C for 25 min. Weight and volume measurements were made after cooling. Expert evaluation on crumb grain and texture was carried out on bread followed by freeze-drying and analysis.

Freeze-dried bread was ground to 20 mesh particle size in a Wiley mill (Arthur H. Thompson Co.) and stored in air-tight containers. Moisture, ash, protein, and fat analyses were carried out using the AACC approved methods (AACC 1983). Fiber determinations were made by the acid detergent fiber (Van Soest 1963), neutral detergent fiber (Goering and Van Soest 1970), and acid detergent lignin (Van Soest 1973) methods to measure cellulose, hemicellulose, and lignin.

[1]Presented at the AACC 70th Annual Meeting, Orlando, FL, September, 1985. Published with the approval of the Director of the North Dakota Agricultural Experiment Station as Journal Article 1506.
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Amino acid analyses were conducted on a Technicon sequential multi-sample automated amino acid analyzer (model TSM-1) using a procedure developed by Spackman, Stein, and Moore (1958). Norleucine was used as an internal standard. Tryptophan was determined by a procedure described by Satterlee et al (1982). Chemical score and discriminant computed protein efficiency ratio (DC-PER) were determined.

Sensory Evaluation

A seven-point hedonic rating scale (Amerine et al 1965, Johnston 1979) was used to evaluate appearance, texture, taste, and over-all rating of oat-bran breads that were baked the day before sensory evaluation. Samples were randomly coded and served individually with distilled water for mouth rinsing.

Statistical Analysis

The statistical analyses of data included mean scores, analysis of variance, and Duncan's multiple range test.

RESULTS AND DISCUSSION

Preliminary baking trials conducted with commercial oat bran proved difficult because considerable oat endosperm adhered to the bran. This necessitated the use of a bran duster to abrade bran and pneumatically remove oat flour. The amount of oat flour removed was 31.9% of commercial bran. Further work was done with bran-dusted oat bran only. Table I shows the particle size distribution of the oat bran. Large, intermediate, and small sizes constituted 29.0, 44.1, and 26.9%, respectively, of the treated bran.

Physical Dough Properties

Studies on the physical dough properties (Table II) showed increased farinograph absorption due to bran addition. Absorption increased with increases in bran in the blends as well as with reduction in particle size. The use of large and intermediate size brans at a 10% level of substitution produced dough of good stability as shown by a mechanical tolerance index, which was poorest for 15% bran blends particularly when small bran was used. Dough stability decreased with the use of small bran at both levels of substitution (10 and 15%). Dough development time (or peak time), when dough reaches maximum consistency, varied with flour replacement levels as well as with bran particle size. Peak time decreased with a reduction in bran particle size. The commercial oat bran used in this study brought about shorter peak times than the oat meal bran used by D'Appolonia and Youngs (1978) in which the oat meal bran was obtained by dry milling commercial oatmeal.

Bread Baking

Mixing oat bran-wheat flour blends with other dough ingredients required scraping the sides of the bowl with a spatula because of the sticky nature of the bran. D'Appolonia and Youngs (1978) reported similar problems with blends containing 20% oat meal bran, oat bran, and high-protein concentrate.

Table II also provides data on baking studies conducted with control and oat bran-flour blends. Baking absorption of the oat bran-flour blends was generally less than that of farinograph absorption. Mixing time was judged by the feel of the dough and its ability to form a film on stretching. The 10% oat bran doughs had mixing times ranging from 3¾ to 4¼ min, whereas 15% oat bran doughs required shorter mixing times of 3¼ to 3¾ min. The effect of bran particle size on mixing times at both levels of substitution was not easily discernible. The time required for bran hydration relative to its surface area must be taken into account. Lorenz (1976) found no differences in mixing times between 10 and 15% replacement doughs when oat hulls were used as a bran source. Punching of bran doughs caused excessive gas exhaustion. The 15% bran doughs were found to be wet with a rough shiny surface. Sheeting of bran doughs produced an inelastic dough.

Bread Evaluation

Table III provides data on the volume of control and oat bran breads as measured by rapeseed displacement. The use of 10 and 15 ppm potassium bromate ($KBrO_3$) improved loaf volume with a more pronounced effect with 15 ppm $KBrO_3$. There was a decrease in loaf volume with increased bran substitution and reduced bran particle size. The smaller loaf volumes obtained from bran-substituted flours might have been caused by poor gas formation and poor gas retention in the dough. Gluten dilution and gums present in the oat bran may have had a strong influence on bread quality. The small bran produced smaller loaf volumes than the

TABLE I
Average Particle Size[a] of Oat Bran Used for Flour Blends

U.S. Standard Sieve Size	Particle Size (μm)	Oat Bran (%)	Bran Size Classification
Over 30	>594	29.0	Large
Over 40	>420	44.1	Intermediate
Through 40	<420	26.9	Small

[a] Means of three replicates.

TABLE II
Farinograph and Baking Data for Oat Bran Wheat Flour Blends

	Farinograph Data				Baking Data	
Source	Blend (%)	Absorption (%)	Development Time (min)	MTI[a] (BU)	Baking Absorption (%)	Mixing Time (min)
Control HRS[b] wheat flour	0	62.1	6½	15	62.1	3½
Oat Bran						
Large	10	67.2	11	10	66.7	4¼
Med	10	67.8	9¾	10	66.7	4¼
Small	10	69.4	6¾	20	68.0	3¾
Large	15	72.7	10	20	68.2	3¼
Med	15	75.6	11	20	69.7	3½
Small	15	76.4	8	30	70.7	3¾

[a] Mechanical tolerance index in Brabender units.
[b] HRS = Hard red spring.

TABLE III
Evaluation of Bread Characteristics

% Flour Replacement with Oat Bran	Bran Size	$KBrO_3$ (ppm)	Volume (cm^3)	Grain and Texture[b]	Comments[b]
0 (control)	···	···	840.00	10.0	
10	Large	0	750 ± 7.5[a]	7.5	
10	Large	10	808.0	8.0	Slightly coarse
10	Large	15	840.00	8.5	Good
10	Med	0	730.0 ± 20.0[a]	7.0	Coarse
10	Med	10	730.0	8.0	
10	Med	15	795.0	8.0	
10	Small	0	675.0 ± 20.0[a]	6.5	
10	Small	10	750.0	7.5	
10	Small	15	755.0	8.0	
15	Large	0	663.0 ± 2.5[a]	5.5	Open and coarse
15	Large	10	730.0	7.0	Slightly open and coarse
15	Large	15	725.0	7.0	Slightly open and coarse
15	Med	0	635.0 ± 0[a]	6.0	Open and coarse
15	Med	10	690.0	7.0	Open and coarse
15	Med	15	700.0	7.0	
15	Small	0	605.0 ± 5.0[a]	5.5	
15	Small	10	640.0	7.0	
15	Small	15	675.0	7.0	

[a] Data based on average of duplicate bakes; other values based on single bakes.
[b] Expert evaluation. Values based on a score of 1–10 with 10 being the best score.

large bran at the same level of substitution. The smaller bran particles are perhaps more strategically distributed within the gluten matrix to affect its gas retention powers in comparison to large bran particles, which are fewer and less well distributed within the dough.

Table III provides information on bread characteristics of control and oat bran breads. The use of $KBrO_3$ at the 10 and 15 ppm levels improved grain and texture at both levels of substitution. Breads made with 15% oat bran had more open cells and coarser texture as judged by physical inspection.

Analytical

The moisture (Table IV) content of oat bran agreed with values found in the literature. Chen and Anderson (1981) reported 8.4% moisture in oat bran. Ash content was 3.02–3.06% in the bran and 2.82–3.14% in oat bran breads.

Crude protein in large bran was slightly lower than in intermediate and small bran. The hard red spring flour used in the study had a protein content of 16.3%. Factors of 5.83 and 5.7 were used for converting percent nitrogen to percent protein in oat bran and flour, respectively. Protein contents of 21–22%, 18.8%, and 19.9-22.9% (N × 6.25) have been reported in oat bran by various workers (D'Appolonia and Youngs 1978, Gould et al 1980). The source, nature of bran, and milling specifications are factors to be considered in interpreting protein variability in the bran.

Dietary fiber analysis of oat bran (Table V) as determined by acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin methods showed the relative concentrations of hemicellulose, cellulose, and lignin in the three bran fractions used in the study. Oat bran had approximately half as much cellulose and lignin as AACC-certified wheat bran and a greater proportion of hemicellulose (Spiller et al 1978). Dietary fiber analysis of control and oat bran breads (Table VI) showed increases in fiber content in oat bran breads. The increases were greater as measured by the NDF method than by the ADF method. This indicated a higher hemicellulose fraction in oat bran breads. NDF increased significantly with increases in bran substitution. NDF in breads also increased with reduction in bran particle size but the cause for this higher NDF value in breads made with small bran particles is not understood. It has been reported that cooking increases dietary fiber (Baker 1976, Kies 1982); polymerization of proteins with carbohydrate could affect the availability of the proteins for digestion. The small bran had more surface area to contact the other dough components. Presumably the amount of indigestible protein-fiber complex formed during baking is higher in the bread with small bran particles than in the bread with intermediate and large sizes of bran. More research is needed to clarify the effects of heating on alterations of dietary fibers. The control bread had an NDF content of 7.88%, whereas 10 and 15% bran breads had NDF contents of 8.51–10.35% and 16.39–23.16%, respectively.

Oat bran breads showed slight but significant increases in protein content over control bread (Table VI). Oat bran particle size did not affect protein content of oat bran bread at either level of substitution (10 or 15%) except in the case of 10% bran bread made with small size bran. Percent protein was calculated as 6.25 × %N in the control and oat bran breads.

Amino Acid Content

Table VII summarizes essential amino acid and histidine composition of oat bran breads and control bread. In general, lysine is the first limiting amino acid in oat bran and control breads. Bran supplementation at both the 10 and 15% levels appeared to increase lysine content in oat bran breads slightly. DC-PER calculated from essential amino acid content alone was 0.46 for control bread and 0.45–0.46 for all oat bran breads. The DC-PER assay estimates protein digestibility from amino acid composition. DC-PER could possibly over-estimate protein digestibility because of the resistance of the cells to digestion. Thus, DC-PER could slightly overestimate the protein nutritional quality. These data indicate that the incorporation of oat bran did not increase protein quality.

Sensory Evaluation

A seven-member taste panel preferred the appearance of 15% oat bran breads made with large size bran followed by bread with 15% intermediate size bran. The appearance of breads made with large, intermediate, and small brans at the 10% level of substitution was liked moderately.

The textures of breads with 15% large bran or 10% small bran

TABLE IV
Proximate Analysis of Oat Bran, Wheat Bran, and HRS Wheat Flour[a]

Composition	Oat Bran Size: Large	Med	Small	Wheat Bran[b]	HRS[a] Wheat Flour
Moisture	8.33	8.51	8.23	10.40	11.70
Crude protein[c]	23.51	24.06	24.10	14.30	16.30
Ash[c]	3.06	3.06	3.03	5.12	0.40

[a] HRS = Hard red spring.
[b] AACC certified food-grade wheat bran R07-3691.
[c] Data are presented on dry basis.

TABLE V
Fiber Composition of Oat Bran (%, dry weight basis)

Composition[a]	Bran Particle Size: Large	Med	Small
ADF: Lignocellulose	5.52	5.66	5.62
NDF: Cell wall material	32.11	33.42	27.95
ADL: Lignin	1.97	1.76	1.92
NDF-ADF: Hemicellulose	26.59	27.76	22.33
ADF-ADL: Cellulose	3.55	3.90	3.70

[a] ADF = Acid detergent fiber, NDF = neutral detergent fiber, and ADL = acid detergent lignin.

TABLE VI
Proximate Composition of Freeze-Dried Standard HRS Wheat and Oat Bran Breads (%, dry weight basis)[a]

Sample	Bran Particle Size	Moisture	Ash[b]	Protein	Fat	ADF[b]	NDF[b]
Standard bread HRS[c] wheat flour	...	2.31	2.88 a	17.63 a	2.13	0.99 a	7.88 a
10% Oat bran bread	Large	2.70	2.87 a	18.15 b	2.44	1.37 ab	8.51 af
	Med	2.86	2.82 b	18.04 b	2.70	1.41 ab	9.70 bf
	Small	3.09	2.95 c	18.45 c	2.36	1.32 ab	10.35 b
15% Oat bran bread	Large	2.84	3.06 d	18.63 d	2.47	1.73 bc	16.39 c
	Med	2.41	3.14 e	18.66 d	2.73	2.05 c	19.69 d
	Small	2.36	3.11 f	18.69 d	3.04	1.37 ab	23.16 e

[a] Figures in a column followed by the same letter are not significantly different from each other ($P < 0.05$).
[b] Ash, acid detergent fiber (ADF), and neutral detergent fiber (NDF) data were subjected to analysis of variance and Duncan's multiple range test.
[c] HRS = Hard red spring.

TABLE VII
Essential Amino Acid Composition and DC-PER[a] of Oat Bran Breads and Control Bread

Amino Acids	Standard Bread	10% Oat Bran			15% Oat Bran		
		Large	Med	Small	Large	Med	Small
Lysine	1.83	1.75	1.88	1.92	1.98	2.02	2.06
Methionine + cystine	3.16	3.04	2.95	3.01	2.41	3.16	2.72
Threonine	2.31	2.01	2.14	2.29	2.58	2.04	2.39
Isoleucine	2.13	2.07	2.23	2.22	2.36	2.28	2.29
Leucine	5.34	5.43	5.64	5.60	5.79	5.97	5.60
Valine	2.87	2.83	2.97	2.86	2.96	2.93	2.94
Phenylalanine + tyrosine	6.33	6.64	7.02	6.51	7.01	7.16	6.83
Tryptophan	0.70	0.93	0.67	0.61	0.76	0.65	0.68
Histidine	2.01	1.99	2.34	2.42	2.08	2.39	2.27
DC-PER[a]	0.46	0.45	0.45	0.45	0.45	0.46	0.45

[a] DC-PER = Discriminant computed protein efficiency ratio.
[b] Values for amino acids are expressed as grams of amino acid per 16 g of N.

were most liked. The 15% small bran breads received the lowest scores. The 10% breads made with large and intermediate size bran and 15% breads made with intermediate size bran were liked moderately.

The judges preferred the taste of 10% breads made with intermediate size bran followed by 15% large bran bread. Breads made with 10% med and 15% large received the highest overall score. The 15% small bran bread was consistently given lowest scores in all categories.

CONCLUSIONS

Farinograph and baking absorption increased with increases in oat bran levels in the formula as well as with decreases in particle size of bran. Loaf volume increased with potassium bromate addition. Reduction in bran particle size and increasing levels of bran reduced loaf volume of oat bran breads. The 10% bran breads had better loaf volume and grain and texture than 15% bran breads as evaluated by an expert. There were significant increases in protein and dietary fiber content of oat bran breads over control breads at the 10% and 15% levels of substitutions. Smaller bran particle sizes increased dietary fiber content as measured by the neutral detergent method. A taste panel preferred 15% bran breads made with large size bran and 10% bran breads made with intermediate size bran.

ACKNOWLEDGMENT

We thank B. L. D'Appolonia for the expert evaluation of breads, Vernon L. Youngs for material assistance and technical help, R. L. Harrold for assistance in the amino acid analysis, and M. L. Dreher for valuable suggestions.

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[Received July 9, 1986. Revision received October 2, 1986. Accepted October 15, 1986.]