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BAKING PROPERTIES AND MICROSTRUCTURE OF YEAST-RAISED BREADS CONTAINING WHEAT BRAN:CARRAGEENAN BLENDS OR LAMINATES

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Abstract

Breads prepared using a commercial prototype sponge-and-dough formulation with no added gluten and containing white wheat bran:carrageenan blends or white wheat bran:carrageenan laminates (10% by weight flour replacement) had acceptable loaf volumes and crumb grain scores. Doughs containing white wheat bran:carrageenan blends had a higher water absorption and longer mixing time than doughs containing wheat bran:carrageenan laminates with the same quantity of carrageenan. The addition of carrageenan to doughs resulted in a higher water absorption value compared to the doughs containing wheat bran only. Breads made with wheat bran:carrageenan (10% flour replacement) had enhanced loaf volume and improved crumb grain score compared to breads with comparable quantities of wheat bran. Scanning electron micrographs of the breads containing 10% flour replacement of the wheat bran:carrageenan blends or laminates may indicate that perforations of the gluten and gelatinized starch matrix in the wheat bran breads containing the carrageenan may be more uniform, and the perforations smaller than in breads containing untreated wheat bran at the same flour replacement level.

Key Words: High fiber breads, wheat bran, carrageenan in breads, wheat bran:carrageenan laminates.

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Introduction

The purpose of baking dough is to present cereal flours in an attractive, palatable and digestible form. In commercial baking, various high fiber ingredients have been added to bread to increase the fiber content; however, adding increased amounts of fiber such as wheat bran to bread can lead to a significant reduction in loaf volume, poor color, texture, mouthfeel, and flavor. Increasing the amount of fiber that can be incorporated into a loaf of bread would have significant nutritional benefits. Wheat bran and the use of fibrous materials in breads has been reviewed by Pomeranz *et al.* (1977) who found that adding high levels of fiber such as wheat bran led to gluten dilution and caused significant reductions in loaf volume.

As early as 1968, Glabe and Jertson determined that adding carrageenan to breads made by continuous mixing resulted in breads with acceptable loaf volumes. In breads, hydrocolloids such as carrageenan bind water affecting the rheological properties of the dough and thus the finished product quality of the baked bread (Bruemmer, 1977).

Scanning electron microscopy (SEM) allows food scientists to study structural features of food products (Aranyi and Hawrylewicz, 1969; Hall and Sayre, 1969; Boyde and Wood, 1969). Due to its large depth of field and magnification range, SEM provides a means for characterizing physical properties and textural attributes of food ingredients in a formulated product. Although SEM has been used to study the microstructure of flour doughs and the changes occurring in the dough during mixing and dough development, there have been few SEM studies of bread structure after baking (Khoo *et al.* 1975; Chabot, 1979; Pomeranz and Meyer, 1984; Bechtel, 1985; Freeman and Shelton, 1991). The primary objective of this research was to study the baking properties of yeast raised bread containing wheat bran: carrageenan blends, or wheat bran:carrageenan laminates and to examine the structure of the breads containing these ingredients by SEM.

Table 1. Sponge-and-dough formulation[a]

Ingredient	weight in grams
Sponge	
Bread flour	70.0
Yeast, compressed	2.5
Water	47.0 (variable)
Fiber ingredient (see Table 2)	
Dough	
Bread flour	30.0
Salt	2.0
Sugar	6.0
Shortening	3.0
Potassium bromate	2.0 μg
Ascorbate (as ascorbic acid)	10.0 μg
Yeast, compressed	2.75
Water	~16.0*

[a]For a single loaf. Procedure: Mix sponge ingredient and ferment 3 hours (80°F). Optimally mix sponge and dough ingredients, proof to an average proof time of 55 minutes based on proof time of flour control, bake at 425°F for 17 minutes in rotary convection oven. Measure loaf volume immediately after baking by rapeseed displacement method.

*Water as required for optimal dough processing.

Table 2. Fiber Replacement Levels[a]

Ingredient	Replacement levels (g) 0%	5%	10%	20%
Flour[b]	100.0	95.0	90.0	80.0
Fiber Ingredient	0.0	5.0	10.0	20.0

[a]Level of fiber ingredient added in place of flour to formulation in Table 1. [b]14% moisture basis.

Materials and Methods

Wheat bran:carrageenan blends

White wheat bran (Fisher Mills, Harbor Island, WA) was mixed with carrageenan (Satigum-CD, Sanofi Bio Ingredients, Germantown, WI) as a dry blend at levels of 95:5 (weight/weight, w/w) or 90:10 (w/w) prior to its incorporation as a fiber ingredient into doughs.

Wheat bran:carrageenan laminates

The laminated fiber ingredients were produced by coating white wheat bran (Fisher Mills, Harbor Island, WA) with carrageenan (Satigum-CD, Sanofi Bio Ingredients, Germantown, WI). Laminates were made by mixing 400 g white wheat bran with varying levels of carrageenan (0. 0.5, 1, 2, 5 or 10% by weight) and then adding water (1,000 ml for mixtures containing 0, 0.5 or 1% carrageenan; 1,200 ml for those containing 2, 5 or 10% carrageenan). The aqueous suspensions were dried using an atmospheric double drum dryer (model ALC-4, Blawknox, Buffalo, NY) operated at a steam pressure of 275 to 300 kPa (40.4-44.3 psi) and a speed of approximately 2.5 rpm. The drums were spaced 0.2 mm apart. This drying treatment allowed the wheat bran and carrageenan to be evenly dispersed.

Table 3. Fiber ingredients and flour replacement levels tested (x) (ND: not determined).

Ingredient	Flour replacement level 5%	10%	20%
Wheat bran	x	x	x
Wheat bran:carrageenan blends (w/w)			
95:5	x	ND	ND
90:10	ND	x	x
Wheat bran:carrageenan laminates (w/w)			
100:0	x	x	x
95.5:0.5	x	ND	ND
99:1	x	x	x
98:2	x	x	x
95:5	x	x	x
90:10	x	x	x

Commercial prototype baking trials

Duplicate laboratory pup loaves (100 g flour/14% moisture basis) were prepared using a sponge-and-dough process patterned after commercial baking specifications [Roman Meal Co., Tacoma, WA (Table 1)]. For control doughs (no added fiber ingredient), 70.0 g of white bread flour [14% moisture basis, (All-Montana Flour, Centennial Mill/ADM Milling Co., Portland, OR) containing 12% protein (14% moisture basis] was used. No gluten was added to this formulation. To the flour, 2.5 g compressed yeast, and 47 ml water was added, and a sponge formed by mixing for 1 minute (Model 100-200 A, 100-200 g mixer, National Mgf. Co., Lincoln, NE). Sponges were fermented for 3 hours at 80°F (26.7°C) in a controlled temperature cabinet (Despatch Industries, Inc., Minneapolis, MN). After fermentation, 30 g flour at 14% moisture, 2.75 g compressed yeast, 6 g granulated sugar, 2 g salt, 3 g hydrogenated vegetable shortening, 20 ppm potassium bromate, 100 ppm ascorbate (as ascorbic acid), and water as required for optimal dough formation, were added. The doughs were mixed until optimal development was reached. Dough temperatures after mixing ranged from 77°F to 80°F (25°C to 26.7°C). Following mixing, the doughs were allowed to rest for 10 minutes at room temperature at 77°F (25°C), scaled, allowed to rest for 10 minutes at room temperature, molded, and then placed into baking pans and proofed 55 minutes in a humidified cabinet at 112°F (44.4°C). Breads were baked in a rotary oven at 425°F (218°C) for 17 minutes.

Wheat bran or wheat bran:carrageenan blends or laminates were added to the formulation in Table 1 (Table 2) with appropriate adjustments made to the water

Table 4. Mixing properties of flour doughs containing wheat bran and wheat bran:carrageenan fiber ingredients.

Product	Sub level (%)	Farinograph[1] Water abs. (%)	Dev. Time (min.)	Mixing Tests Opt. mix. time (min.)	Mixing Tests Water abs. (%)
Flour (Control)[2]	ND	59	9.0	2.5 ± 0.2^{a}	66.0 ± 0.5^{ab}
Wheat Bran[3]	5	ND	ND	2.4 ± 0.2^{b}	67.5 ± 0.8^{a}
	10	64	14.0	2.6 ± 0.1^{c}	67.5 ± 0.6^{b}
	20	70	16.5	3.8 ± 0.3	71.0 ± 1.3^{ab}
Wheat bran:carrageenan blend					
95:5 (w/w)[3]	5	ND	ND	4.0 ± 0.0^{a}	67.0 ± 1.4^{ab}
90:10 (w/w)	10	67.5	33.0	4.0 ± 0.7^{abc}	68.0 ± 0.0^{ab}
	20	74.5	50.0	5.5 ± 0.8^{abc}	75.5 ± 0.5^{ab}
Wheat bran:carrageenan laminate					
100:0 (w/w)	5	ND	ND	3.1 ± 0.5	68.0 ± 0.6^{ab}
	10	63	11.5	3.4 ± 0.1	68.0 ± 0.0^{ab}
	20	69	12.0	4.5 ± 0.3^{abc}	73.0 ± 2.3^{ab}
99.5:0.5	5	ND	ND	3.0 ± 0.6	67.0 ± 0.7^{ab}
99:1	5	ND	ND	2.6 ± 0.1	67.0 ± 0.8^{ab}
	10	ND	ND	3.5 ± 0.1	68.0 ± 0.5^{ab}
	20	ND	ND	4.4 ± 0.1^{abc}	73.0 ± 2.6^{ab}
98:2	5	ND	ND	3.0 ± 0.5	67.0 ± 0.6^{ab}
	10	ND	ND	3.8 ± 0.3^{ab}	70.0 ± 0.5^{ab}
	20	ND	ND	4.6 ± 0.4^{abc}	74.0 ± 2.5^{ab}
95:5	5	ND	ND	3.6 ± 0.3	67.0 ± 1.5^{ab}
	10	64	13.0	4.6 ± 0.3^{abc}	70.0 ± 0.5^{ab}
	20	72	19.5	5.4 ± 0.6^{abc}	73.5 ± 1.9^{ab}
90:10	5	ND	ND	4.2 ± 0.5^{abc}	66.0 ± 1.7^{ab}
	10	65	20.5	5.7 ± 1.4^{abc}	70.0 ± 0.5^{ab}
	20	72.5	28.0	6.0 ± 0.6^{abc}	70.0 ± 0.8^{ab}

ND - not determined.
[1]Water absorption and development times for farinograms are single values.
[2]Sample averages for flour controls are from four loaves from two baking trials (n = 8).
[3]For doughs containing fiber ingredients, two replicate loaves from two baking trials were analyzed (n = 4).
[a-c]Values within a single column for the breads containing the wheat bran blends or laminates were significantly different ($p < 0.05$) from the control (a), wheat bran (5%) (b), or wheat bran (10%) using one-way analysis of variance and the Fisher primary least square difference (PLSD) test.

addition at the "dough" stage for optimal mixing. For each level of fiber tested, duplicate loaves of bread were prepared in two separate trials. The fiber ingredient and replacement levels used in the breads are given in Table 3. Immediately after baking, loaf volume of each loaf was measured by the rapeseed displacement method and subjective measurements of crumb grain and texture were made (Rasco *et al.* 1991). Water absorption values for the wheat flour doughs were conducted using the constant flour weight-variable dough weight method [AACC (1986) method 54-21].

Scanning electron microscopy

Breads were sliced to a thickness of 0.5 inch (1.25 cm) within 1 hour after baking and frozen at -20°F (-28.9°C). The frozen slices were lyophilized [48 hours at 30-60 mTorr, -50 to -55°C (Freezemobile VI, Virtis, Inc., Gardiner, NY)]. Surfaces were exposed for sampling by removing a thin layer approximately 1.0 mm thick. From the remaining bread, small pieces no greater than 4 mm in height and 10 mm in length were cut and mounted on SEM specimen holders with colloidal silver paste (#16032, Ted Pella Inc., Redding, CA) to increase conductivity. The mounted samples were sputter coated with gold-palladium (15 nm layer) for a total of 4 minutes (2 minutes on top surface, 1 minute each of 2 side view surfaces) at 10 mA in a Hummer V Sputter Coater (Model HUV, Technics EMS Inc., Springfield, VA). Once prepared, the specimens were examined with a JEOL scanning electron microscope (Model JSM-840 A JEOL Ltd., Tokyo) operated at an accelerating voltage

Table 5. Baking Parameters for Breads Containing Wheat Bran and Wheat Bran:Carrageenan Fiber Ingredients.

Product	Sub level (%)	Dough wt. (g)	Loaf wt. (g)	Loaf vol. (mm^3)	Crumb Grain[1]
Control[2]	0	174.1 ± 1.5	147.9 ± 2.2	1,040 ± 53[a]	S
Wheat Bran[3]	5	174.7 ± 1.6	147.7 ± 2.6	989 ± 29[b]	S
	10	176.0 ± 0.5	150.0 ± 0.7	998 ± 24[c]	S
	20	179.4 ± 1.6	154.3 ± 0.9	849 ± 24[a,b,c]	S
Wheat Bran:Carrageenan Blends[3]					
95:5 (w/w)	5	174.2 ± 0.2	146.0 ± 0.9	1,145 ± 28[a,b,c]	S
90:10 (w/w)	10	174.5 ± 0.9	148.2 ± 1.1	1,092 ± 19[b]	S
	20	175.6 ± 3.0	149.5 ± 1.3	913 ± 49[a]	Q-S
Wheat Bran:Carrageenan Laminates[3]					
100:0 (w/w)	5	176.0 ± 1.5	149.6 ± 2.2	982 ± 28	S
	10	175.9 ± 1.1	148.9 ± 2.5	929 ± 19[a]	S
	20	180.7 ± 3.4	155.5 ± 1.4	781 ± 30[a,b,c]	Q-S
99.5:0.5 (w/w)	5	175.8 ± 1.4	148.1 ± 2.3	984 ± 11	S
99:1 (w/w)	5	174.1 ± 1.5	148.5 ± 1.2	1,000 ± 41	S
	10	176.0 ± 0.5	148.6 ± 1.3	976 ± 21	S
	20	181.2 ± 2.6	154.6 ± 1.6	851 ± 51[a,b,c]	Q-S
98:2 (w/w)	5	175.0 ± 1.4	148.8 ± 0.7	1,034 ± 30	S
	10	177.4 ± 0.6	151.5 ± 1.1	1,028 ± 9	S
	20	181.1 ± 2.1	154.8 ± 0.8	881 ± 43[a,b,c]	Q-S
95:5 (w/w)	5	174.9 ± 1.1	149.9 ± 1.3	1,085 ± 18[b]	S
	10	177.0 ± 0.8	150.6 ± 1.4	1,060 ± 23	S
	20	179.1 ± 1.1	153.0 ± 0.7	868 ± 44[a,b,c]	Q-S
90:10 (w/w)	5	174.9 ± 0.8	147.6 ± 1.9	1,259 ± 40[a,b,c]	S
	10	176.3 ± 1.3	149.5 ± 1.3	1,090 ± 23[b]	S
	20	176.4 ± 0.8	151.8 ± 0.7	839 ± 21[a,b,c]	Q-S

[1]Crumb grain rated using a three-point scale with S = satisfactory, and Q = questionable (Rasco *et al.* 1991).
[2]Values for control (no added fiber ingredient) were from four baking trials with two loaves per trial (n = 8).
[3]Values for fiber containing breads were from two baking trials with two loaves per trial (n = 4).
[a-c]Values within a single column for the breads containing the wheat bran blends or laminates were significantly different ($p < 0.05$) from the control (a), wheat bran (5%) (b), or wheat bran (10%) using one-way analysis of variance and the Fisher PLSD test.

of 3.5 kV. Specimens were photographed on positive/negative 4" x 5" instant sheet film (Polaroid 55 Professional, Polaroid Corp., Cambridge, MA).

Results

Table 4 summarizes water absorption values, development times and optimal mix times for doughs containing from 5-20% of the various wheat bran based fiber ingredients. Development times were longer for the wheat bran:carrageenan blends than for the wheat bran:carrageenan laminates containing either the same level of carrageenan, or when the fiber ingredients was added to the bread at the same flour replacement level. Addition of carrageenan led to higher water absorption values for the doughs relative to doughs containing wheat bran at the same flour replacement levels. The dough containing wheat bran blends and laminates had higher water absorption values ($p < 0.05$) than the doughs containing no added fiber (control) or the untreated wheat bran at the 5% flour replacement level. Mix times for wheat bran:carrageenan blends (10% or 20% flour replacement level) were higher ($p < 0.05$) than for the control or breads containing wheat at either a 5% or 10% flour replacement level. Mix times for doughs containing the wheat bran:carrageenan laminates (20% flour replacement level) were also higher ($p < 0.05$) than the mix times for the control or doughs containing wheat bran at the 5% or 10% flour replacement level. However, mix times for the doughs containing the wheat bran:carrageenan laminates at the 10% flour replacement level were only significantly different from the control ($p < 0.05$) at higher carrageenan concentrations (Table 4).

Table 5 shows the results of the baking tests including loaf volume and crumb grain scores. Addition

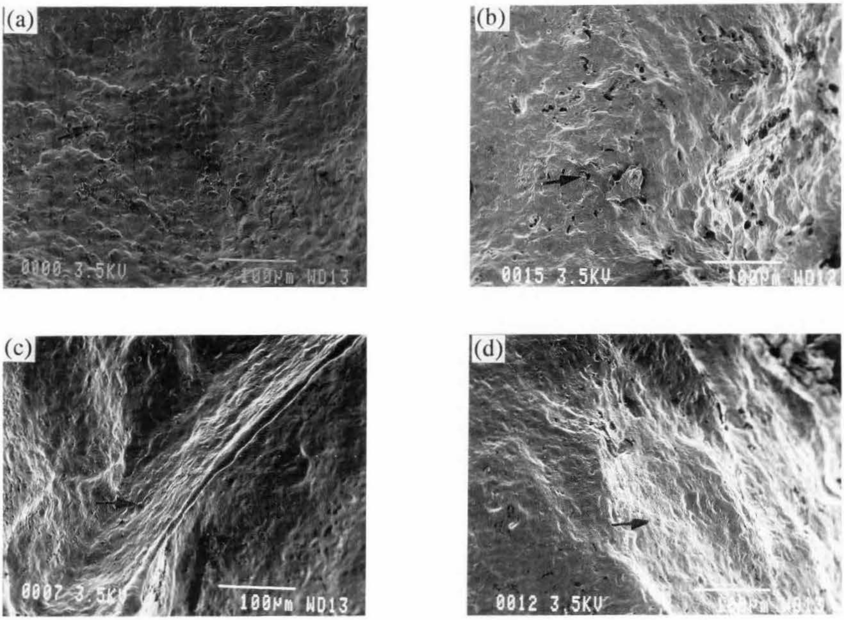

Figure 1. Scanning electron micrographs of breads; note perforation of gluten-starch matrix (arrows). **a)** Control, no added fiber ingredients. **b)** Wheat bran, 10% flour replacement level. **c)** Wheat bran:carrageenan blend (90:10 w/w), 10% flour replacement level. **d)** wheat bran:carrageenan laminate (90:10 w/w), 10% flour replacement level. Bars = 100 μm.

of carrageenan either as part of a white wheat blend, or as a laminate, resulted in breads which had greater loaf volumes than breads containing comparable levels of wheat bran but no carrageenan. Breads made with 5-10% of the wheat bran:carrageenan laminates (98:2, 95:5 or 90:10 w/w) had loaf volumes which were similar to or greater than the control (no fiber ingredient). The loaf volumes of the breads containing 5-10% of the following laminates (98:2, 95:5, or 90:10 w/w) were 3 to 25% higher than for breads containing either 5% or 10% white wheat bran (Table 5).

Structural features of freeze-dried bread specimens examined by SEM are shown in Figure 1. White wheat bran or white wheat bran:carrageenan blends or laminates were added at a 10% flour replacement level. Breads containing white wheat bran:carrageenan blend or laminate (90:10 w/w) (Figures 1c and 1d) appeared to have a more uniform distribution of perforations, and smaller perforations of the gluten-starch matrix than the wheat bran control (Figure 1b).

Discussion

A predicted advantage for the wheat bran:carrageenan fiber ingredients was that such ingredients would incorporate the beneficial properties of both a soluble and insoluble fiber ingredient into a single material. The "lamination" process involved heating the wheat bran and carrageenan in an aqueous medium permitting the hydration of the gum along with various components in the wheat bran. A large number of the starch granules contained in the bran were damaged during the lamination process with the laminate containing a significant amount of gelatinized starch. Damaged starch plays an important role in water absorption by doughs (Shelton and D'Appolonia, 1985). It must be present at optimal levels relative to the concentration of α and β amylase to produce desirable characteristics during bread-making such as adequate gas production, baking absorption and production of browning reaction products during baking. Subjecting bran to a lamination process such as the one described here may significantly reduce development times and may be an advantage in straight dough systems (Table 4). For the 20% substitution level, the development time for the dough containing the wheat bran which had been hydrated and drum dried (wheat bran:carrageenan laminate 100:0] was significantly lower than for the dough containing untreated wheat bran. The optimal mix times for the doughs containing the laminates were higher than for those containing untreated wheat bran, suggesting that any advantage of a more rapid initial hydration of the fiber ingredient would be lost in a sponge-and dough process.

In the control breads (no added fiber ingredient), dough development was as expected (Table 4). However, in the doughs containing the carrageenan blends, the carrageenan formed doughs with a high lubricity which made it difficult to monitor dough development. Optimal mix times was longer for the doughs containing the carrageenan blend or the carrageenan laminates. Gums can function to entrap wheat bran and bind larger aggregates of wheat bran together (Shaw and Sharma, 1989). As the concentration of either the wheat bran: carrageenan blend or laminate increased in the dough formulation, the elasticity of the dough during mixing increased dramatically. The changes in mixing properties of the doughs containing the carrageenan blends could pose problems to commercial bakers by increasing mix time and making dough handling more difficult.

Without the addition of carrageenan, the development time for the wheat bran containing doughs was longer than for those containing the hydrated drum-dried wheat bran (wheat bran:carrageenan laminate 100:0 w/w). Dough development times were higher for the wheat bran:carrageenan blends than for the corresponding laminate. These results suggest that the hydration and heating of the bran during the lamination process may have gelatinized a portion of the starch in the wheat bran, and also hydrated bran protein and other wheat bran components allowing for easier hydration of the fiber product during fermentation and mixing (Table 4). Development times for all doughs containing carrageenan increased proportionately as the level of carrageenan increased.

Baking and farinogram absorption values may have differed due to variations in the rate of hydration of the fiber ingredients during the three hour fermentation period utilized in the sponge-and-dough baking process. Hydration of bran fiber is relatively slow (Rasco *et al.*, 1990). Crumb grain scores for all of the fiber containing breads were satisfactory at flour substitution levels of five or ten percent. However, the mixing properties of doughs prepared with either the wheat bran:carrageenan blend or the wheat bran:carrageenan laminates may make these materials difficult to handle in a commercial operation.

Multiple observation of scanning electron micrographs revealed differences between the crumb structure of the control and the fiber containing breads. The control (no added fiber ingredient; Fig. 1a) had a fine crumb structure composed of a well-developed network of thin protein sheets and most probably swollen and expanded starch granules supporting gluten structure (Pomeranz and Meyer, 1984). When bran was added to the doughs at a 10% flour replacement level, perforations in the gluten-starch matrix appeared to be larger and less uniform. Adding wheat bran as a component of a carrageenan blend or laminate (Figs. 1c and 1d) did not appear to have as great an effect on the appearance of the gluten-starch matrix as did addition of wheat bran alone.

Conclusions

The addition of carrageenan at 2-10% of a wheat bran based blend or laminate increased loaf volumes relative to bread which contained the same quantity of wheat bran. Water absorption and mix times were higher for the doughs which contained wheat bran:carrageenan blends or laminates than those containing only wheat bran. Scanning electron micrographs of the breads containing 10% flour replacement of the wheat bran:carrageenan blends or laminates may indicate that these treated fiber ingredients may have a less detrimental impact on the integrity of the gluten-starch matrix than wheat bran at the same flour replacement level as indicated by a more uniform distribution of small perforations in the matrix.

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Discussion with Reviewers

R. Moss: Although one recognizes that limitations are imposed by time, availability of equipment and other resource restrictions, I would like to note that it would have been useful to have included micrographs of the doughs, particularly as the authors indicate that dough development was difficult to monitor. The incorporation of some light microscopy would also have been useful to confirm whether coating material was gluten of carrageenan.

Authors: We did not have the capability to examine the doughs by SEM. The commercial baking facility where all the doughs were prepared was 60 miles from the university. We had no way of ensuring that any doughs we would examine in SEM would be representative of what was 'baked off', by the time we were able to get the doughs back to the university, get them properly frozen, and lyophilized for SEM examination, many changes could have taken place. Use of light microscopy would not make it any easier to discern whether coating material was gluten or carrageenan unless there were specific staining procedures of which we are not aware.

Obtaining a good measurement for an optimal mix time (dough development) for the wheat bran:carrageenan blend was difficult because of the way this particular dough mixed; this was the only treatment where we had any difficulty measuring optimal mix time, the mix times for the other breads were easy to measure.

R. Moss: Many references are made to differences in thickness of gluten films; where and how were these measurements made? It would be helpful if the authors could label figures to illustrate differences in film thickness.

Authors: We made numerous observations of these breads. We observed differences in the number, thickness and in the integrity (breakage) of gluten strands between breads made with these different treatments. Unfortunately, we do not have the capability to take actual measurements from the SEM or to digitize these images so that we could do computer image analysis and obtain this information. This is one of the reasons that the baking and dough development data is important, since the baking data provide an indication of the strength of a gluten network in a dough.

P. Resmini: The authors discuss about the handling difficulties in industrial production of doughs with high levels of wheat bran:carrageenan blends. They should also examine the influence of the tested levels of fiber on the organoleptic characteristics and on the acceptability of this type of bread.

Authors: We have examined the sensory characteristics of these breads. Crumb grain scores are a sensory measure of texture conducted by an expert panel. We have some other data on the sensory properties of similar high fiber breads which we have not included as part of this paper because we felt that it was not relevant.

P. Resmini: Was the dried specimen cut by a razor or was it fractured without mechanical tools? In this last case, the fracture plane will expose the surface delimiting large air cells (i.e., more than 50-100 μm; see Khoo *et al.*, 1975; Pomeranz and Meyer, 1984).

Authors: We cut a small slice from lyophilized breads with a razor and took slices from crumb edge so that samples would be consistent between treatments. Any artifacts that may have been introduced should have been consistent from treatment to treatment.

P. Resmini: In no case do the bread images exhibit the large gas cells observed in the literature citations, but only very small air cells. These gas cells are quite similar to the "perforations of gluten film" shown by Angold [Cereal and Bakery products. In: Food Microscopy. Vaughan JG (ed.). Academic Press, 1979, 75). Please comment.

Authors: One of our premises was that the breads made with the carrageenan laminates had larger number of small air cells than breads which contained wheat bran but no added carrageenan. You have apparently noticed the same thing. Pressure equilibration, and the number and type of air cells that this would produce, would be directly related to the strength of the gluten network. We feel that the addition of gum to the fiber bread would enhance the resilience of the dough (increase its plasticity) providing strength to the gluten network which is compromised when bran is added. This is a possible reason why we were able to see larger loaf volumes in the breads containing the bran:carrageenan laminates or blends than in the breads containing the same quantity of bran. Bran weakens gluten structure either through a 'gluten diluting' effect or because the bran particles actually puncture air cells causing them to collapse (very difficult to verify). Adding the gum may have stabilized air cells allowing then to remain stable without collapsing during dough development or during the early stages of baking.

P. Resmini: On the basis of our experience, the presence of fibers generally weaken the dough structure and, consequently, the gluten strength. How do the authors account for the presence of thicker gluten strands in the fiber breads? Did the mixing test (performed with mixograph) indicate significative differences between the control and the fiber-bread mixograms? I emphasize that the differences in the protein structure (thickness of strands, etc.) are more easily seen on the dough before baking (see Khoo *et al.*, 1975).

Authors: Thicker gluten strands in fiber breads are from the air cells that survive. Air cell collapse is thought to be one of the reasons that bran containing breads have a lower loaf volume.

We did not run mixographs as this equipment was not available. Instead, we ran farinographs to measure dough development. Changes in dough structure before baking may tell you more about the dough structure, but not necessarily what will happen to this structure during the early stages of baking. We wanted to look at breads because we thought that SEM of the breads might give us a better indication of the role carrageenan might have played in enhancing loaf volume rather than SEMs of the doughs. The effect of the air cell expansion which occurs during the early stages of baking would not have been observed if we looked at doughs instead of breads.

M.E. Camire: Were any statistical analyses applied to the findings? The mixing tests' results are fairly close, so readers might like to know the least significant difference among this data.

Authors: We did conduct statistical analyses for water absorption (Table 4), mix time (Table 4), and loaf volume (Table 5) values using ANOVA ($p < 0.05$) and the Fisher PLSD post-test. Statistical comparisons are reported for the control and wheat bran containing breads (5% and 10% flour replacement levels) and the other treatments.

M.E. Camire: Recently concerns have been raised regarding the safety of heated carrageenan in foods, since heat degrades polymers into smaller molecular weight fractions which irritate the small intestine. Would you expect the combined effects of lamination and baking to produce such fragmentation in breads containing carrageenan?

Authors: We do not expect that there would be significant fragmentation of carrageenan using the lamination process described here. Any food safety problems with breads containing carrageenan at the higher levels used in these bread formulations (< 0.01 g carrageenan per g of bread) would be slight.

M.E. Camire: Why was carrageenan selected as the source of soluble fiber in this study? Pentosans and other gums may produce similar results. Have you investigated other gums?

Authors: We used a number of other sources of soluble fiber in the laminated wheat bran ingredients. These included all of the common food gums, modified cellulose, oat, corn, barley, and a variety of different pectins. We observed the greatest increase in loaf volume by using carrageenan. We also observed browning and flavor development in some of the laminates containing pectin which carry through to this bread even when added at low levels (< 2% of a laminate) making the pectin product unsuitable for breads. Some of the wheat bran-food gum laminates have unusual rheological properties which may make them useful in other food applications but which make them difficult to use in breads. We are also studying possible applications for some of these wheat bran-gum laminates in other food products.