Increased Yield of Bread Containing Citrus Peel Fiber[1]

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ABSTRACT

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Bread yield is economically important to commercial bakers. Flour was replaced with 2.5% citrus peel fiber or 0.23% pectin. Pectin increased water absorption by 0.6% in the farinograph, 2% in the mixograph, and 4% in baking. Citrus peel fiber had a greater effect, increasing water absorption by 6.5% in the farinograph, 7% in the mixograph, 6.4% in the mixolab, and 10% in baking. Citrus peel fiber strengthened dough while pectin had a weakening effect. Loaves containing citrus peel fiber had decreased loaf volume but crumb grain characteristics similar to control loaves. Pectin did not affect loaf volume but had a deleterious effect on the crumb grain. Neither citrus peel fiber nor pectin affected bread firming. Citrus peel fiber increased loaf weight by increasing water absorption, indicating that low levels of citrus peel fiber in the bread formula is an effective way to increase bread yield.

Bread yield is of economic importance to commercial bakers. Bread yield is the quantity of bread that can be produced from a given weight of flour. Although bread volume is important, bread is sold by unit weight. Thus, increasing the weight of dough produced from the same weight of dry ingredients will result in more bread (higher yield). Water loss from bread dough during baking is controlled by oven temperature, baking time, surface area of the bread, and the water absorption of the dough. Increasing the water addition to the dough formula is a practical way to increase bread yield with essentially no increase in processing costs. Higher water absorption leads to higher moisture in the resulting bread and increased bread yield (Tipples and Kilborn 1968; Czuchajowska et al 1989; Puhr and D'Appolonia 1992; Miller et al 2008).

Standardized white bread produced in the United States can contain up to 38% water (USDA 2003). There is no limit on the water content of nonstandardized bread. Most flours will not tolerate the level of water needed to obtain a final bread moisture content of 38%. If the water level in the formula is too high, the resulting dough becomes wet, sticky, and cannot be processed. Therefore it is necessary to use additives to increase the water absorption of the dough.

Fiber is well known for its high water holding capacity. Fibers used in breadmaking increase water absorption at high addition levels. Historically, only insoluble materials containing bran and cellulose were considered to be fiber. Traditional sources of fiber used by bakers have included whole grains, cereal bran, cellulose, and its derivatives, fruit fractions, vegetable fractions, and oil seed fractions including defatted meals or hulls (Dubois 1978; Vetter 1984). New definitions now characterize dietary fiber as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human intestinal tract (Anonymous 2001). Recent advances have made dietary fibers such as resistant starches, inulin, polydextrose, β-glucans, maltodextrins, aleurone, oligofructose, and fructooligosaccharides available on a commercial scale for use in food products (Pszczola 2006).

Fiber is often added to baked products at levels of 10–20% (fwb) to increase the fiber content of the final product to meet dietary fiber claims of "excellent" or "good" source of dietary fiber. Many researchers have looked at the effect of a wide variety of fibers in high-fiber bread (Pomeranz et al 1977; Prentice and D'Appolonia 1977; Colmey 1978; D'Appolonia and Youngs 1978; Toma et al 1979; Nagai et al 1980; Sosulski and Wu 1988; Sharif and Butt 2006; Filipovic et al 2007; Sadawarte et al 2007; Mohamed et al 2008; Yeo and Seib 2009). All reported that when added at high levels, fiber dramatically decreased loaf volume and had a negative effect on crumb texture, making it more coarse and crumbly. The reasons for this are that the fiber dilutes the flour protein level and also interferes with gluten development so gas retention in the dough is decreased (Pomeranz et al 1977; Dubois 1978). Volume and texture of high fiber breads can be improved by using high protein spring wheat or by adding high levels of vital wheat gluten and oxidants (Dubois 1978).

Alternatively, fiber can be added at low levels as a functional ingredient. Some useful functions of fiber include moisture management, shelf-life extension, gelling, and fat reduction (Lundberg 2005). In this case, the increase in dietary fiber content is marginal to moderate.

Citrus fiber-based ingredients are not new to the food industry. Fiber from the edible portions of oranges including juice sacs, segment membranes, pulp, and pectin find use in a wide array of food products. Pectin, one of the predominant components of citrus fruit fiber, plays an important role in moisture binding and gelling of sweet spreads, beverages, dairy, and baked products (Lundberg 2005). Expanded pulp fiber binds up to 12 times its weight in water and has been marketed as a shortening replacer in baked foods (Lundberg 2005; Pszczola 2006). The albedo portion of citrus peel is a rich source of dietary fiber including pectin, cellulose, and hemicelluloses. However, the extremely high levels of astringent compounds such as naringin and limonin in citrus peel make it unsuitable for human consumption (Baker 1994). Using new techniques, citrus peel can be processed to remove the astringent compounds to produce a nutritional, functional dietary fiber (Jones 2006). The objective of this study was to determine whether citrus peel fiber could be used as a functional ingredient in bread production to increase water level in the formula and thereby increase bread yield.

MATERIALS AND METHODS

Materials

Commercially milled, malted hard wheat flour containing 13.3% moisture, 0.515% ash (14% mb), and 10.5% protein (14% mb) was provided by ADM Milling (Kansas City, MO). Dried citrus peel fiber (CitraFiber) was provided by Natural Citrus Products (LaBelle, FL) contained 83% dietary fiber and 9.39% pectin. Pectin from citrus peel (containing >74% galacturonic acid) was purchased from Sigma-Aldrich (St. Louis, MO).

Water Retention Capacity

Water retention capacity was determined by Approved Method 56-10.02 (AACC International 2010). Distilled water was used in place of alkaline water. Flour was replaced with 2.5% citrus peel fiber or 0.23% pectin. Citrus peel fiber or pectin was blended with flour before water addition. All samples were tested in triplicate.

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Dough Properties

Flour was replaced with 2.5% citrus peel fiber or 0.23% pectin. Citrus peel fiber or pectin was blended with flour before adding water. Controls containing no citrus peel fiber or pectin were also evaluated. All evaluations were run in triplicate at optimum water absorption.

Dough water absorption and mixing properties were evaluated using mixograph (Approved Method 54-40.02) and farinograph (Approved Method 54-21.01). The behavior of the dough during mixing and heating was evaluated with the mixolab (Approved Method 54-60.01) (AACC International 2010). Mixolab parameters measured included absorption (level of water needed to achieve a dough consistency of 1.1 Nm during the mixing phase); stability (length of time the consistency remains at ≤1.1 Nm during mixing at 30°C); C2 (minimum consistency during initial heating from 30 to 60°C); C3 (peak consistency during the second heating stage from 60 to 90°); C4 (minimum consistency during holding at the 7-min holding period at 90°C); and C5 (maximum consistency after cooling to 50°C). Dough strength and extensibility were measured using the TA.XTPlus texture analyzer with the SMS/Keiffer Rig (Stable Micro Systems/Texture Technologies). Flour (10 g, 14% mb), 0.2 g sodium chloride, and water (optimum) were mixed in the mixograph to optimum development for each treatment. After mixing, the dough was gently formed into a rectangle and placed on the grooved base of the Teflon former that had been generously oiled with mineral oil. The cover was placed on top of the dough then the former was placed in the clamp and tightened. Excess dough that extruded from the edges of the former was cut off and discarded. After 30 min, the clamp was removed and the top of the former was slid back to reveal a single dough strip. Only full strips were tested. The dough strip was gently lifted from the former without stretching and placed on the grooved region of the sample plate. The sample plate was placed in the testing rig with the probe hook positioned beneath the strip. The dough strip was pulled upward by the hook until it ruptured. The test protocol was to measure force in tension, 2.0 mm/sec pretest speed, 3.3 mm/sec test speed, 10 mm/sec posttest speed, 75 mm distance, and 5 g trigger force. Maximum force (g) and distance to rupture (mm) were taken as resistance to extension and dough extensibility, respectively. Four separate doughs were made for each treatment with five strips tested per dough.

White Pan Bread Preparation

Bread was baked as pup loaves using Approved Method 10-10.03 straight-dough procedure with 90 min of fermentation (AACC International 2010). The bread formula consisted of flour (100 g, 14% mb), shortening (3 g), instant active dry yeast (2 g), sugar (6 g), salt (1.5 g), and ascorbic acid (50 ppm). Flour was replaced with 2.5% citrus peel fiber or 0.23% pectin. The citrus peel fiber or pectin was blended with the flour before water addition. Controls containing no citrus peel fiber or pectin were also evaluated. Water absorption and mix time were optimized for each treatment. Dough-handling properties were evaluated subjectively. Proofed doughs were weighed immediately before placing in the oven and baked loaves were weighed 1 hr after removal from the oven. The loss in weight was assumed to be moisture loss during baking. Loaf volume was measured by rapeseed displacement. Crumb grain was evaluated subjectively on a scale of 1 (poor) to 8 (excellent). Crumb color, evaluated using a CR-310 Minolta color meter, was reported as Hunter *L,a,b* values. All treatments were baked at least in triplicate.

Bread Texture

Bread was prepared as described above with the addition of 0.5 g of calcium propionate into the formula as a mold inhibitor. After cooling, the loaves were double-bagged in polyethylene bags and stored at room temperature (74°F) for texture testing. Crumb firmness, elasticity, and moisture content were measured 1, 7, and 14 days after baking.

Loaves were sliced into five slices 25 mm thick. The end slices (heels) were discarded and the center three slices were measured. Crumb firmness and elasticity were measured using a TA.XTPlus texture analyzer (Stable Micro Systems/Texture Technologies) with a modified version of Approved Method 74-09.01 (AACC International 2010). Individual slices were laid flat on the base of the TA.XTPlus and compressed 7 mm (25% compression) at a speed of 1 mm/sec using a cylindrical probe 25 mm in diameter. The compression was held for 30 sec. Firmness was the force in grams required for a 25% compression (6.25 mm depth) of the slice. Elasticity was taken as the force at 37 sec (force required to hold the compression for 30 sec) divided by the peak force at 7 mm and multiplied by 100 to convert to percent. Higher values indicate the crumb was more elastic and sprung back after the compression while lower values indicate the crumb was gummy and did not spring back. Three loaves (three slices per loaf) per treatment per day were evaluated.

After firmness and elasticity measurements were taken, the moisture content of the center slice of each loaf was measured using Approved Method 44-15.02 two-stage moisture procedure (AACC International 2010). Three loaves were measured per treatment.

Statistical Analyses

Data was evaluated using JMP Statistical Discovery software (JMP v.5, SAS Institute, Cary, NC). Statistically significant differences were determined using the Tukey test at $P < 0.05$.

RESULTS

Dough Properties

The level of 2.5% citrus peel fiber was determined in preliminary baking experiments. As the level of citrus peel fiber was increased from 0 to 3.5%, the crumb grain of the loaves became poorer, darker in color, and developed an off-flavor. At the 2.5% level, the loaves exhibited grain characteristics, color, and flavor similar to control loaves. The citrus peel fiber contained 9.39% pectin. To determine whether the pectin was the active component in the citrus peel fiber, pectin isolated from citrus was also evaluated. Pectin was added at 0.23%, the level present in 2.5% citrus peel fiber.

The water holding capacity of the control flour (70.4% fwb) was not different from the flour containing 0.23% pectin (69.6%). However, the water holding capacity of flour containing 2.5% citrus peel fiber was significantly higher at 80%.

The addition of citrus peel fiber and pectin significantly increased dough water absorption (Table I). The addition of pectin increased water absorption by 0.6% in the farinograph and 2% in the mixograph. French and Hill (1985) and Galal and Johnson (1976) both reported increased water absorption in bread doughs containing added pectin. Citrus peel fiber had a greater effect than pectin, increasing farinograph absorption by 6.5% and mixograph absorption by 7%.

It is well known that mixing time increases significantly as water absorption is increased (Finney and Shogren 1972). However, the effect of citrus peel fiber and pectin on optimum mixing time was relatively small. In the farinograph, there was no difference in mixing time between control doughs and those containing citrus peel fiber, while the addition of pectin significantly decreased mixing time. Although water level was significantly higher, citrus peel fiber and pectin increased mixograph mixing time by only 30 sec compared to the control flour. There was no difference in mixing time between doughs containing citrus peel fiber and pectin.

Neither pectin nor citrus peel fiber affected farinograph stability or mix tolerance index (MTI) (Table I). Citrus peel fiber did not significantly alter dough resistance to extension (force) or extensibility (distance) as measured using the Keiffer Rig. Pectin significantly increased resistance to extension but had no effect on extensibility.

TABLE I
Effect of Citrus Peel Fiber (CPF) and Pectin on Dough Properties[a]

	Farinograph				Mixograph		Keiffer Test	
Treatment	Water Abs (%)[b]	Mix Time (min)	Stability (min)	MTI (BU)	Water Abs (%)[b]	Mix Time (min)	Force (g)	Distance (mm)
Control	61.8c	4.5a	9.8a	30a	63c	4.0b	33.9b	41.7a
CPF	68.3a	4.8a	10.4a	30a	70a	4.5a	31.0b	41.4a
Pectin	62.4b	3.6b	9.3a	40a	65b	4.5a	42.0a	30.1a

[a] Values in a column followed by different letters are significantly different ($P = 0.05$).
[b] Percentage on a flour weight basis (fwb).

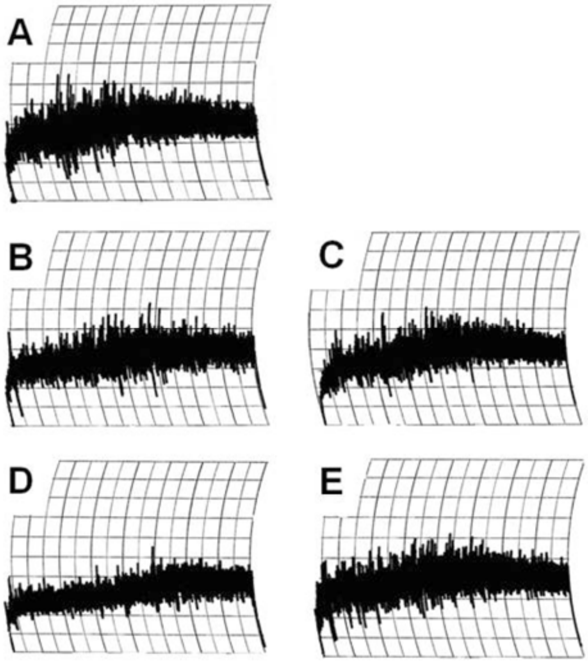

Fig. 1. Mixograms of doughs with varying water absorption (%, fwb). Control flour at 63% absorption (**A**); 65% absorption (**B**); and 70% absorption (**D**); flour with 0.23% pectin at 65% absorption (**C**); flour with 2.5% citrus peel fiber at 70% absorption (**E**).

Neither pectin nor citrus peel fiber significantly altered the general shape or tolerance of the mixograph curve compared to the control flour when mixed at the higher optimum water absorptions (Fig. 1). In the mixograph, the width and shape of the curve indicate optimum water levels. As the dough becomes too wet and slack, the mixograms become narrower and begin to exhibit a characteristic swayback during the development period (Finney and Shogren 1972). This effect can be seen in Fig. 1. Curve A is the mixogram of the control flour at optimum water absorption (63%, fwb). Increasing the water absorption to 65% resulted in a curve (B) that was narrower than curve A during the development period, indicating that the water level was too high and the dough was starting to become slack. When the water level in control doughs was increased to 70% (curve D), the entire curve narrowed, became flatter, and a slight swayback occurred in the development period, indicating that the water level was excessive. The optimum mixograph absorption of doughs containing 0.23% pectin was 65% (curve C) which is similar to curve B, indicating that doughs containing pectin were slightly weaker than the control doughs. Doughs containing 2.5% citrus peel fiber mixed with the optimum water level of 70% (curve E) were dramatically wider and stronger than control dough mixed with 70% water (curve D). In fact, curve E was similar to the control flour mixed with its optimum water level of 63% (curve A). This indicates that the citrus fiber was holding the excess water and the doughs did not become weak and slack with the excess water.

The mixolab measures dough consistency over time as temperature is gradually increased to provide information about dough development time, protein breakdown, starch gelatinization, enzyme activity, and gel strength (Collar et al 2007; Rosell et al 2007; Dubat 2010). Doughs containing 0.23% pectin had the same water requirement as control doughs; however, doughs containing 2.5% citrus peel fiber required significantly more water (6.4%) to achieve the same consistency (Table II). Mixolab stability of doughs containing citrus peel fiber was significantly longer, while mixolab stability of doughs containing pectin was significantly shorter than control doughs. The same trend was seen in the C2 values. Pectin-containing doughs had significantly lower C3 values than control doughs. However, citrus peel fiber did not affect C3 values compared to control or pectin-containing doughs. Control doughs exhibited significantly higher starch gel stability (C4) and retrogradation (C5) than pectin-containing doughs which were significantly higher than doughs containing citrus peel fiber.

White Pan Bread

An even greater increase in absorption was observed in test baking. Bake absorption was increased by 4% with the addition of pectin and 10% with citrus peel fiber (Table III). Both additives increased mixing time by 1 min. Doughs containing citrus peel fiber were not wet, slack, or sticky after mixing and exhibited good viscoelastic properties during fermentation and make-up. Doughs containing pectin were less cohesive during mixing, tending to stick to the sides of the mixing bowl. They were also less elastic and slightly sticky during sheeting and make-up.

As expected, increased water absorption resulted in significant increases in dough weight (Table III). All loaves lost ≈18% moisture during baking; thus loaves containing citrus peel fiber were significantly heavier than control loaves.

Citrus peel fiber decreased loaf volume, while pectin had no effect. Control loaves were white in color with a grain score of 5. The crumb grain of loaves containing citrus peel fiber was similar to control loaves with a score of 5; however, Hunter *L* and *a* values were lower while *b* was higher, resulting in a slightly creamy color. The crumb grain of pectin-containing loaves had a white color similar to the control but the grain was inferior with open coarse cells; thus receiving a lower crumb grain score of 4. Galal and Johnson (1976) reported that low levels of pectin (0.25 and 0.5% fwb) decreased loaf volume, grain score, and texture while French and Hill (1985) reported a loss of mean hedonic score in sensory evaluation of breads containing added pectin.

As expected, crumb firmness increased and elasticity decreased during the storage period. Although the crumb moisture content of loaves containing citrus peel fiber was significantly higher than control loaves throughout the 14-day storage period, there was not a significant difference in the firmness of the loaves (Table IV). This was surprising as it has been reported that bread containing higher moisture content is less firm (Rogers et al 1988; Patel et al 2005). Neither citrus peel fiber nor pectin affected the elasticity of the bread crumb. Loaves containing citrus peel fiber were more elastic the day after baking but there was no difference on days 7 and 14. This indicates that the addition of the citrus peel fiber and pectin along with the dramatic increase in water absorption did not cause the bread to become gummy in texture.

TABLE II
Effect of Citrus Peel Fiber (CPF) and Pectin on Mixolab Properties[a]

Treatment	Water Abs (%)[b]	Stability (min)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)
Control	57.8b	8.03b	0.39b	1.71a	1.18a	1.69a
CPF	64.2a	9.49a	0.41a	1.66ab	1.00c	1.45c
Pectin	58.4b	7.27c	0.35c	1.62b	1.12b	1.57b

[a] Values in a column followed by different letters are significantly different ($P = 0.05$).
[b] Percentage on a flour weight basis (fwb).

TABLE III
Effect of Citrus Peel Fiber (CPF) and Pectin on Dough and Bread Properties[a]

Treatment	Water Abs (%)[b]	Mix Time (min)	Dough Wt Before Bake (g)	Bread Wt After Bake (g)	Wt Loss In Bake (%)	Loaf Volume (cm^3)	*L*	*a*	*b*
Control	67c	3.8b	178.4c	146.4b	17.9a	905a	97.7a	0.21a	2.3b
CPF	77a	4.8a	186.7a	152.0a	18.6a	854b	95.0b	–0.04b	2.6a
Pectin	71b	4.8a	181.6b	148.6ab	18.2a	888ab	97.2a	0.13a	2.2b

[a] Values in a column followed by different letters are significantly different ($P = 0.05$).
[b] Percentage on a flour weight basis (fwb).

TABLE IV
Effect of Citrus Peel Fiber (CPF) and Pectin on Bread Crumb Properties[a]

	Firmness (g)			Elasticity (%)			Crumb Moisture (%)		
Treatment	Day 1	Day 7	Day 14	Day 1	Day 7	Day 14	Day 1	Day 7	Day 14
Control	144a	445a	797a	65b	52a	48a	41.5b	37.8b	35.4b
CPF	141a	441a	816a	67a	52a	49a	45.0a	40.1a	38.3a
Pectin	145a	519a	781a	66ab	51a	48a	43.0ab	38.0b	36.8ab

[a] Values in a column followed by different letters are significantly different ($P = 0.05$).

DISCUSSION

Citrus peel fiber dramatically increased the amount of water that could be added to the dough without the typical large increase in mixing time and weakening of the dough. Mixolab stability and C2 were significantly increased, indicating citrus peel fiber had a dough strengthening effect. Although loaf volume decreased, the loaves maintained an acceptable volume with no loss in crumb grain score. The crumb maintained its elasticity and did not exhibit a gummy texture even though moisture content was dramatically increased. Citrus peel fiber did not have an effect on crumb firmness (shelf life).

Pectin also increased water absorption but to a lesser extent. Decreased mix time, slightly slacker mixograms, decreased mixolab stability, decreased C2 values and less elastic dough handling properties during baking indicate that pectin weakened the dough. Pectin did not affect loaf volume; however, the grain was poorer.

Although the pectin content of the citrus peel fiber was high, pectin did not have the same effect as citrus peel fiber in dough. Thus it appears that the effect of the citrus peel fiber was caused by other factors. Water-soluble nonstarch polysaccharides have improved gas retention, gluten extensibility, and crumb grain characteristics (Hoseney et al 1969; Wang et al 1998). The citrus peel fiber contained 83% dietary fiber of which 30% was soluble. The improving effect of the citrus peel fiber may be partially due to the high concentration or type of water-soluble nonstarch polysaccharides present.

CONCLUSIONS

The higher water absorption of doughs containing citrus peel fiber resulted in an increased loaf weight of the baked bread. This indicates that the addition of low levels of citrus peel fiber is an effective way to increase bread yield. The increased water absorption allows the baker to produce more dough from a given weight of dry ingredients at little additional cost.

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