Improvement of Brown Bread Quality by Prehydration Treatment and Cultivar Selection of Bran

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ABSTRACT

Different bran pretreatments and bran cultivars were investigated with the aim of alleviating the adverse effects caused by bran addition in brown (fiber-rich) bread. Three different bran treatments: hydration, wet heat, and wet oxidation, all hydrate bran before its addition to other breadmaking ingredients. Four different bran cultivars were investigated. All treatments improved brown bread quality significantly, resulting in larger, softer loafs. All treatments resulted in an increase in the water absorption of brown bread doughs and a decrease in potentially oxidizable substances (POS) in brans. It is suggested that prehydration treatment activates bran lipoxygenase which oxidizes POS in bran, reducing bran's contribution to brown bread dough. A further reduction of these substances is caused by a washout effect of the treatments. On average across all bran cultivars, the hydration and wet oxidation treatments improved brown bread quality significantly more than the wet heat treatment, which also reduced the bran POS significantly less than the other treatments, probably due to its rapid inactivation of lipoxygenase. The bran cultivars differed significantly in their effects on brown bread quality, suggesting that bran selection according to cultivar should be considered.

Wheat bran is a component of whole wheat and brown flours that is responsible for the low specific volume and dense crumb texture of traditional wholemeal and brown bread (Shogren et al 1981, Rogers and Hoseney 1982, Gan et al 1989). The production of whole wheat bread and brown bread with the same loaf volume as white bread is, therefore, more expensive because of extra flour and technology required (Rogers and Hoseney 1982). South Africa is probably unique in the world in that 46% of all bread produced is brown pan bread (Randall et al 1995), it being a staple food of the majority of the population. Lower income families cannot afford to pay more for a high-technology modified loaf. These families, however, need the nutritional benefit of brown bread. It is therefore important to improve the quality of South African brown bread without adding significantly to the cost of a loaf.

Brown bread in South Africa is produced by adding back a maximum of 15% bran to white base flour as opposed to increased extraction milling (Cheetham 1988). This adding of bran presents the baker with the opportunity to optimize baking performance and consequent loaf quality by adding a specific bran cultivar or bran that has been modified. Some research has been done on the treatment of bran before its addition to other breadmaking ingredients (Lai et al 1989a–c; Wootton and Shams-Ud-Din 1986). Studies suggested that the detrimental effects of bran could be overcome by using an optimized water absorption (Lai et al 1989c), and the detrimental effects of shorts (a mixture of germ, aleurone, and pericarp layers) could be overcome by soaking them, thus allowing endogenous lipoxygenase to function and oxidize glutathione and methoxylhydroquinone (Lai et al 1989a). A reconstituted whole wheat bread (containing 16.3% bran plus 12.7% shorts) with a loaf volume equal to that of a white bread control was obtained with a sponge-and-dough baking method by allowing lipoxygenase (enzyme active soy flour) to oxidize the glutathione from the germ and using optimum absorption (Lai et al 1989b). In another study (Wootton and Shams-Ud-Din 1986), wheat bran was extracted with tap water, the extract was freeze-dried, and the extracted bran (residue) dried at 70°C before addition to flour and other breadmaking ingredients. The bran residue increased loaf volume, while the bran extract decreased loaf volume as compared to bread baked with ordinary bran. It was also found that the bran residue increased dough water absorption while the bran extract decreased dough water absorption. The bran residue also tended to increase dough stability. No information on the effect of the cultivar of wheat bran on brown bread quality could be found, except that some wheat cultivars have unexpected strengthening effects on dough characteristics and baking quality (Özboy and Köksel 1997).

In this article, we report on the effects of pretreatments of bran, including hydration, wet heat, and wet oxidation on various attributes of the bran, dough, and final brown bread quality. All treatments were characterized by hydration of bran before addition to other breadmaking ingredients. We also report on the effect of some different cultivars of bran on brown bread quality.

MATERIALS AND METHODS

Sample Preparation

Wheat of four different cultivars: one standard commercial sample (*Triticum aestivum* L.) and three pure cultivars (Palmiet, Tugela DN, and Molen) were obtained from the Small Grain Institute, Bethlehem, South Africa. Wheats were milled on a Miag mill to an extraction rate of 74%. Bran was collected and sieved to a particle size >1 mm and <2 mm. A white flour, with a protein content (N × 5.7) of 11.7% (12% mb), was obtained from a commercial mill to act as common base flour. Bran and flour samples were divided into baking and test-sized batches, vacuum packed, and stored at –20°C.

Bran Oxygen Uptake

Three open containers, each with 1 L of oxygenated water (± 30 mg of O_2/L) at ±10°C, were prepared. To the first container nothing was added. To the second container, 144 g of heat-treated bran of nominal particle size >1 mm and <2 mm was added. To the third container, 144 g of bran (untreated) of the same particle size was added. The oxygen concentration in each of these containers was measured before bran addition, after bran addition, and on every minute for 15 min, using a microprocessor oxygen meter (OXI 196, Wissenschaftlich-Technische Werkstätten, Weilheim, West Germany). The bran was heat-treated by transferring a 500 g of bran sample to a 2-L glass bottle, sealing it air-tight and autoclaving at 121°C for 2 hr.

Bran Hydration Treatment

Bran (144 g) was weighed into a muslin bag with a draw string. The closed bag was suspended in an excess of water at 10°C for 15 min to allow complete water absorption and agitated frequently during suspension. It was removed from the water and wrung out to achieve a constant weight (500 g). The wet bran was transferred into the dough mixer with the other baking ingredients and water addition was adapted accordingly.

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Bran Wet Heat Treatment

The same method as for the hydration treatment was employed, except that bran (144 g) was suspended in an excess boiling water (97.4°C) for 15 min to allow complete water absorption and inactivation of endogenous enzymes. A preliminary experiment showed that the treatment was sufficient to inactivate lipase .

Bran Wet Oxidation Treatment

The same method as for the hydration treatment was employed, except that bran (144 g) was suspended in 1 L of oxygen-enriched water (30 mg O_2/L) at 10°C for 15 min.

Lipase Activity

Lipase activity of bran was determined by the method of Sullivan and Allison Howe (1933), whereby lipase in the bran hydrolyses triacetin (added substrate) under standardized conditions into free fatty acids that are determined titrimetrically with standard base.

Lipoxygenase Activity

Lipoxygenase activity of wheat bran was determined by the method of Schwarz and Pyler (1984) for determining lipoxygenase activity of malting barley. The principle of this assay is that lipoxygenase oxidizes linoleic acid into conjugated dienes that are measured spectrophotometrically at 234 nm.

Potentially Oxidizable Substances (POS)

Total reducing substances were determined using Approved Method 10-01 (AACC 1995), modified by using 5 g of sample and extracting with 100 mL of trichloroacetic acid for 24 hr. A thiosulphate concentration of 0.625*M* was used to give a blank of 9.6 mL (instead of 3 mL) when titrated against 3 mL of 0.01*M* iodine.

Breadmaking

A mechanical dough process was used. The baking tests were repeated three times for each of the four bran cultivars. A premix for the brown bread was prepared on % basis (w/w) including: 48.01% salt, 24.01% fat, 12.00% sugar, 12.00% soya flour, 3.60% calcium propionate, 0.18% ascorbic acid, and 0.19% fungal α-amylase. The common base flour (88%, w/w), treated or untreated bran (12%, w/w), premix (2.5%), yeast (2%) dissolved in part of the water, and water were all added separately to the mixing bowl. The total water added for the control and for the brown bread baked with treated bran was 64 and 65%, respectively. The mixer was set to achieve a 11 Wh/kg energy input. Two pieces of dough (900 g) were weighed and put through a dough former. The dough was allowed to rest under a plastic cover for 10 min. It was then kneaded out (pressed flat by palm of hand to a thickness of ≈25 mm), folded double, and put through the dough former. The dough was placed in pans with the folded sides at the bottom. The dough was proofed at 40°C (75–80% rh) for 65 min, then baked for 30 min (230°C).

Farinograph

Standard method 115 (ICC 1991) was used, except that wheat bran, either dry or hydrated, replaced 12% (w/w) of the flour.

TABLE I
Effect of Bran Hydration Treatment and Level of Water Addition on Loaf Volume, Loaf Height, and Bread Firmness of Brown Bread Baked with a Standard Commercial Bran[a]

Bran Treatments	Loaf Volume (cm^3)	Loaf Height (mm)	Bread Firmness (N)
None (64% water)	3,380 ± 39b	148 ± 3b	4.60 ± 0.13b
None (65% water)	3,190 ± 11a	139 ± 1a	4.98 ± 0.06c
Hydration (64% water)	3,390 ± 23b	147 ± 1b	4.90 ± 0.0bc
Hydration (65% water)	3,530 ± 12c	156 ± 1c	3.44 ± 0.07a

[a] Mean ± standard error, $n = 6$. Mean values in the same columns with different letters are significantly different ($P < 0.05$).

Bread Loaf Measurements

Loaf heights were measured and loaf volumes were determined by rapeseed displacement.

Firmness of Bread Measurements

Firmness is defined as amount of force required to compress product by a preset distance. Approved Method 74-09 (AACC 1995) for measuring bread firmness using a universal testing machine was used. The bread firmness of all the loaves was measured 24 hr after baking. All loaves were treated the same before the measurements were made. Each loaf was left to cool, then placed in a plastic bag and left at ambient temperature until bread firmness was measured.

Image Analyses of Bread Crumb Structure

An image analysis system (Quantimet 520, Cambridge Instruments, Cambridge, U.K.), including a macro scanner, was used to generate data on the brown bread crumb structure. Photocopies of bread crumb structure of three replicate loaves were prepared and set areas (49,000 mm^2) were scanned under optimized light conditions. In each set area, the number of holes, area of each hole, and roundness of each hole were measured. The procedures were described in the manufacturer's manual (Image Analysis System Operator Manual V03.00, Cambridge Instruments).

RESULTS AND DISCUSSION

Conceptualization of Bran Treatments

Lai et al (1989a,c) suggested that, due to the competition for water between bran, starch, and gluten in fiber-rich (brown) bread, gluten is not sufficiently hydrated to develop optimally at "normal" water absorption levels, resulting in a reduction in loaf volume. Table I shows that the control brown loaf was larger and less firm at 64% water addition than at 65%, indicating 64% water addition was the normal optimum for untreated bran. This was confirmed by the feel of the dough. After hydration treatment, the reverse was found, showing that the water addition optimum increased after treatment. The brown bread loaf made with treated bran and a 65% water addition was also significantly larger and softer than the loaf made with untreated bran and a 64% water addition, indicating that the hydration treatment of bran before mixing with other breadmaking ingredients allowed the dough to accommodate an extra 1% of water. The extra water is presumably needed for optimum hydration of all flour components, irrespective of the speed of hydration, as implied by Lai et al (1989a,c).

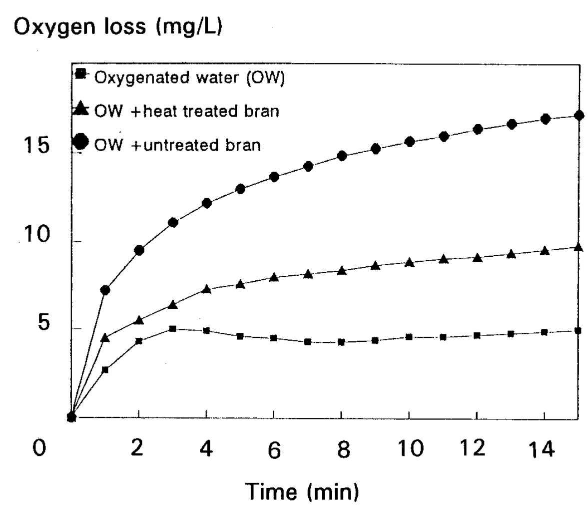

Fig. 1. Oxygen loss (mg/L) by oxygenated water, oxygenated water containing heat-treated bran, and oxygenated water containing untreated bran.

Different hydration treatments were devised to investigate the possible roles of enzymes and oxygen in this effect.

A wet oxidation treatment was designed to encourage oxidation by lipoxygenase of potentially oxidizable substances (POS) which include: polyunsaturated free fatty acids (PUFFA), glutathione, and other reducing substances. According to Barnes and Lowry (1986), free fatty acids and other lipid degradation products may act as foam (dough) destabilizers and depress loaf volume. A wet heat treatment was designed to inactivate the heat-labile bran enzymes because Tait and Galliard (1988) found a close relationship between lipase activity and poor baking performance with storage of wholemeal. Figure 1 shows clearly that bran absorbed oxygen from oxygenated water. Heat-treated bran absorbed substantially less oxygen. As stated, the heat treatment inactivated lipase and, therefore presumably, the other heat-labile enzymes, including lipoxygenase. Although lipase is the limiting enzyme in the oxidation of PUFFA (Windholz 1983), it is not oxygen-dependent and, therefore, it is suggested that the difference in oxygen consumption is due to lipoxygenase as this enzyme is oxygen-dependent and suspected of oxidizing POS (Galliard 1986, Lai et al 1989a).

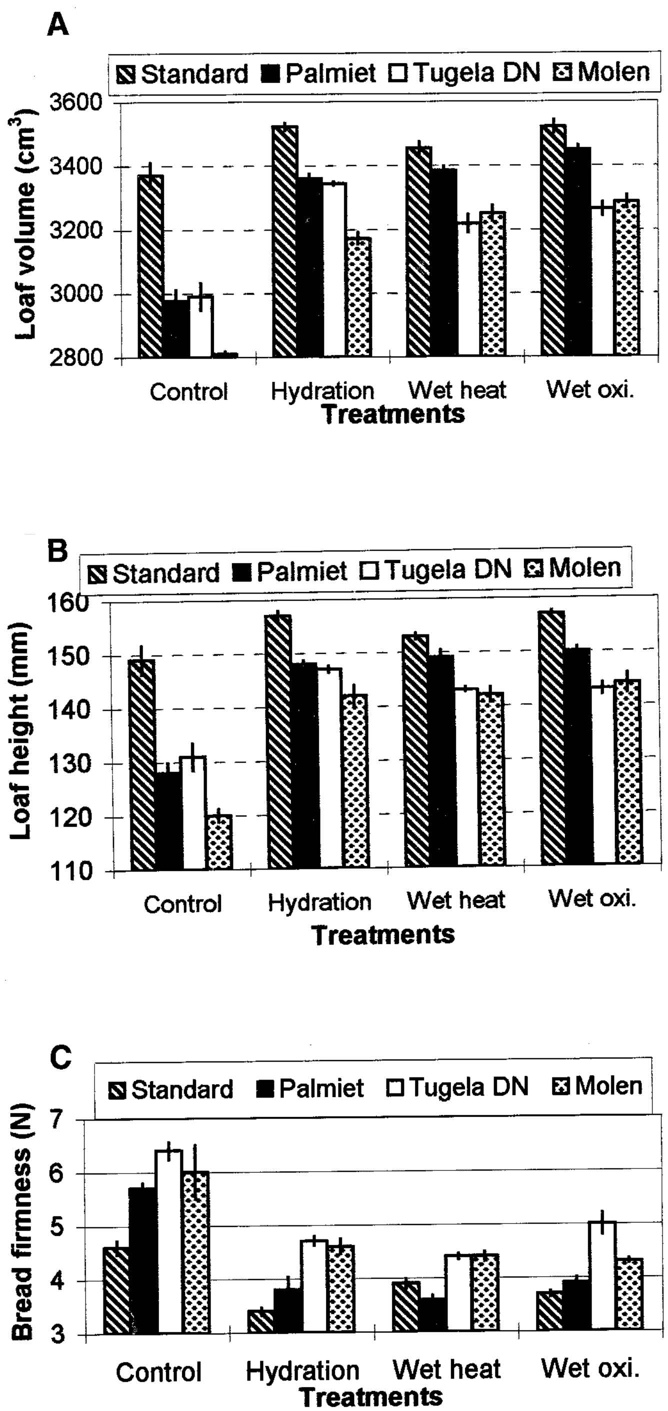

Fig. 2. Effect of bran treatment and bran cultivar on brown bread: loaf volume (**A**), loaf height (**B**), bread firmness (**C**). Bars indicate standard error.

Effect of Bran Treatments on Brown Bread

The effects of different bran treatments and bran cultivars on loaf volume, height, and firmness are shown in Fig. 2. On average, across all bran cultivars, the treatments increased loaf volume by ±10%, loaf height by ±10%, and bread firmness by ±27%. This was accompanied by an increase in the brown bread dough water absorptions of 1%. The wet heat treatment increased loaf volume significantly less than the other two treatments, with no significant difference between them (Fig. 2A). No significant differences were noted regarding treatment effects on loaf height (Fig. 2B) and bread firmness (Fig. 2C), suggesting volume was the more sensitive indicator.

The bran treatments had little effect on bread crumb structure (results not shown), though the wet oxidation treatment did significantly increase the size of the holes in the crumb, possibly due to the addition of oxygen which could have boosted yeast fermentation.

The above results suggest that the effects of the bran hydration treatments are chemical in nature, possibly primarily by hydration of polysaccharides. Kulp (1968) found that wheat pentosans take up 10 times their own weight of water. It is also possible that prehydration, with agitation, washes out free reduced glutathione, which is freely soluble in water (Windholz 1983) and known to disrupt disulfide bonding (Schofield and Chen 1995). This is strongly supported by work done by Wootton and Shams-Ud-Din (1986), who found that bread and dough were adversely affected by the aqueous bran extract and to a lesser degree the bran itself. They also found that the bran residue improved loaf volume, dough strength, and dough water absorption. Additionally, as prehydration of bran would activate endogenous lipoxygenase, it would oxidize POS and decrease them (Lai et al 1989c), hence relieving the adverse effects.

Effect of Bran Cultivar on Brown Bread

Bran cultivar also had a significant effect on loaf volume, loaf height, and bread firmness (Fig. 2). In terms of loaf volume (Fig. 2A), the best quality brown bread was produced using the standard commercial bran, followed by the Palmiet, and then Tugela DN bran. Molen bran gave the smallest loaf volume. It should be noted, however, that the water addition was only optimized for the standard commercial bran and was kept constant for all the other brans. While this subsequently proved to be also optimal for Palmiet bran, it was insufficient for Tugela DN and Molen brans.

Table II shows that the effect of bran cultivars on crumb structure was reasonably well related to the brans' breadmaking performance in terms of loaf volume (Fig. 2A). Standard commercial bran produced the largest, softest loaves with the smallest, roundest, and most holes. This agrees with findings of Gan et al (1992), who found that one of the major adverse effects of bran was to distort the shape of the holes in the crumb.

TABLE II
Effect of Bran Cultivar on the Number of Holes, Mean Size, and Roundness of the Holes Detected in a Bread Slice[a]

Bran Cultivar	Area (mm^2)	Roundness[b]	Count
Standard	3.86 ± 0.13a	2.22 ± 0.03a	401 ± 13c
Palmiet	7.19 ± 0.09b	2.39 ± 0.03c	251 ± 13b
Tugela DN	6.49 ± 0.23b	2.33 ± 0.03bc	254 ± 13b
Molen	5.85 ± 0.17ab	2.29 ± 0.03b	238 ± 13a

[a] Mean ± standard error, n = 24. Mean values with different letters are significantly different ($P < 0.05$). Data are the means from all bran treatments.
[b] Perfectly round object = 1, irrespective of size.

Effect of Bran Treatments on Dough Characteristics

While all the prehydration treatments increased baking water absorption, farinograph water absorption showed the opposite (Fig. 3). It has, however, long been recognized that the farinograph is a poor predictor of bakery water absorption (Rao and Rao 1991). Further, predictions of flour water absorption using the farinograph is probably rendered meaningless with addition of prehydrated bran. Dough arrival time and degree of softening were also decreased, while dough stability was increased. Hydration and wet oxidation treatments gave the greatest stability, which gave the largest bread loaves (Fig. 2A). Increased dough stability and subsequent loaf volume increase are supported by the work done by Wootton and Shams-Ud-Din (1986), who found that bran residue (extracted with tap water) increased both dough stability and loaf volume. This led us to speculate that dough stability is inversely related to POS content, which in turn would be inversely related to lipoxygenase activity; the higher the lipoxygenase activity the greater the dough stability, due to reduced disulfide bond disruption resulting from POS.

Effect of Bran Cultivar on Dough Characteristics

The farinograph data for the doughs with the different bran cultivars (Fig. 4) confirm the anomaly regarding optimized water absorptions and subsequent baking quality. The relative ranking changing from standard commercial bran, Palmiet, Tugela DN, and Molen (Fig. 2A) to Tugela DN, Molen, standard commercial bran, and Palmiet as expressed by dough stability (Table III). However, the water absorptions of the doughs made with brans of different cultivars correlated well with subsequent dough characteristics. Brans with higher water absorptions (Tugela DN and Molen) gave doughs with longer development times and greater stabilities. It is suggested that different bran cultivars have differing chemical compositions and the subsequent hydration kinetics influence breadmaking performance .

Effect of Bran Treatments on Enzyme Activities and POS

The bran lipoxygenase activity, POS, and lipase activity were all reduced by bran treatment (Table III). The common effect may be largely explained by a wash-out effect during bran hydration.

Though lipase activity (Table III) was significantly affected by treatment (hydration and wet oxidation decreasing it and wet heat almost inactivating activity), the change in activity did not seem to explain the improvement in bread quality. Tait and Galliard (1988) found a close relationship between lipase activity and poor baking performance with storage of wholemeal. However, in the work reported here, the wet heat treatment inactivated lipase significantly more than the hydration and wet oxidation treatments but still produced the poorest brown bread loaves of the three treatments. As the ingredients used for this research had been stored under ideal conditions, there should have been no storage lipase activity interaction, and all the brans probably had similar amounts of free fatty acids present at the onset of breadmaking. It is therefore suggested that it is the products of lipase activity (PUFFA and POS) and not lipase activity directly, that adversely affects baking performance.

Lipoxygenase activity (Table III) was affected in a manner similar to that of lipase, with the wet heat treatment being the most effective in reducing its activity. However, lipoxygenase activity correlated well with baking performance. As suggested, the higher the lipoxygenase activity (hydration and wet oxidation), the lower the level of POS (Table III), the greater the dough stability (Fig. 3), and the greater the loaf size (Figs. 1 and 2A). In other words, the prehydration treatments activated lipoxygenase resulting in a decrease in POS so that less disulfide bond disruption occurred. However, it was also evident that the hydration and wet oxidation treatments only decreased POS by ±50% (Table III). It is thus possible that if POS could be further decreased, a further increase in loaf size could be obtained.

TABLE III
Effect of Bran Treatments on Bran Lipase Activity, Lipoxygenase (LOX) Activity, and Potentially Oxidizable Substances (POS)[a]

Treatment	Lipase Activity[b]	LOX Activity[c]	POS[d]
Control	52.63 ± 2.90d	4.44 ± 0.61c	9.1 ± 0.1c
Hydration	43.61 ± 2.67c	2.37 ± 0.37b	5.2 ± 0.6a
Wet heat	0.81 ± 0.25a	0.17 ± 0.03a	7.7 ± 0.2b
Wet oxidation	40.86 ± 2.25b	2.44 ± 0.48b	4.7 ± 0.8a

[a] Mean ± standard error, n = 24. Mean values with different letters are significantly different ($P < 0.05$). Data are the means of all bran types.
[b] Units are mL of 0.1*M* NaOH/g of bran.
[c] Measured as μm – U/g of bran, where one unit of lipoxygenase activity is the amount of enzyme that will catalyze the formation from linoleic acid of 1.0 mol of conjugated dienoic hydroperoxy linoleic acid/min/mL of extract.
[d] Proportional to 0.635 mL of $S_2O_3^{2-}$.

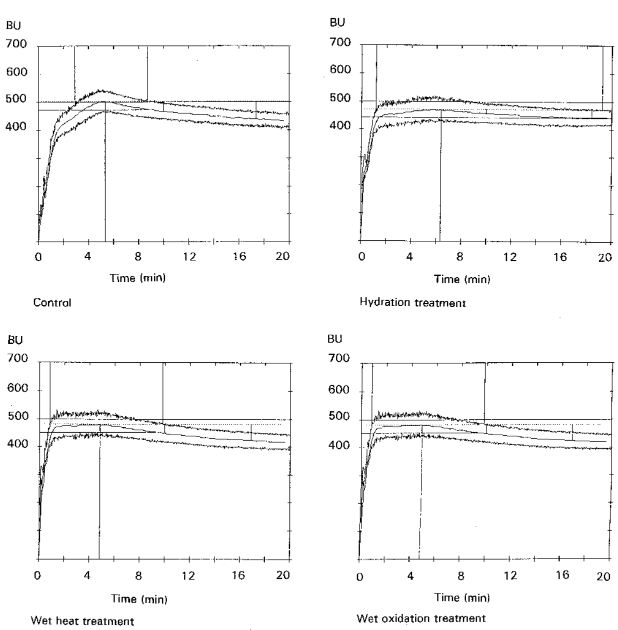

Fig. 3. Farinograms for treated and untreated brown bread doughs prepared with commercial bran.

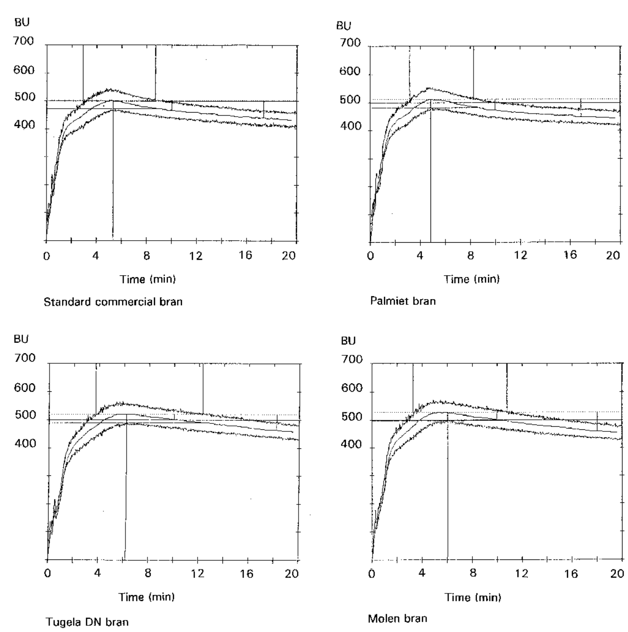

Fig. 4. Farinograms for untreated brown bread doughs prepared with commercial bran and three bran cultivars.

CONCLUSIONS

All the bran prehydration treatments improved brown bread quality significantly, resulting in larger, softer loaves. Overall, without considering bran cultivars, the hydration and wet oxidation treatments improved brown bread quality significantly more than the wet heat treatment.

There are several possible mechanisms for this improvement: an increase in the optimum water absorption of the brown bread doughs resulting in improved hydration of all brown flour components, irrespective of the speed of hydration; a decrease in potentially oxidizable substances (POS) in the brans through lipoxygenase activation; and possibly a wash-out effect, resulting in greater disulfide bonding and hence a stronger dough.

Bran cultivar influenced the quality of brown bread significantly. Brans of different cultivars had different water absorptions that correlated well with subsequent dough characteristics. Brans with higher water absorptions gave doughs with longer development times and greater stabilities. The baking performance of bran cultivars (loaf volume) correlated well with the subsequent bread crumb structure; the largest loaves were characterized by many relatively small and round holes in the crumb. It is suggested that different bran cultivars have differing chemical compositions and the subsequent hydration kinetics influence bread crumb structures differently.

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