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Chapter 33

Bran in Bread: Effects of Particle Size and Level of Wheat and Oat Bran on Mixing, Proving and Baking

Grant M Campbell¹, Marcela Ross² and Lidia Motoi²

¹Satake Centre for Grain Process Engineering, School of Chemical Engineering and Analytical Science, The University of Manchester, Manchester, M60 1QD, UK

²New Zealand Institute for Crop and Food Research, Lincoln, New Zealand

Abstract

The effects of adding wheat and oat bran, at different levels and milled to varying particle size ranges, to dough formulations were investigated, with respect to aeration and dough development during mixing, expansion during proving and final baked loaf characteristics. Addition of bran reduced the density of the dough at the end of mixing, largely because of the increased water absorption, with bran particle size having little effect on dough density. Wheat bran substituted for flour at 7.5% increased the capacity of the doughs to expand during proving, but despite this the baked loaf volumes were lower, and even lower at 15%. Grinding the wheat bran had little effect on optimum work input, water absorption and expansion during proving, but gave slightly lower loaf volumes and a finer crumb texture. The low correlation between proving expansion and baked loaf volume suggested that the effects of the wheat bran in bread formulations occurred during baking. By contrast, adding oat bran reduced both the maximum expansion capacity of the dough during proving and the baked loaf volume, suggesting that the oat bran exerted its effects largely during proving. Grinding the oat bran gave lower optimum work inputs and higher water absorptions, and reduced both proving expansion and baked loaf volumes.

Keywords: Bread dough; wheat bran; oat bran; mixing; proving; proof; baking; aeration; dynamic dough density, particle size, work input, water absorption

1. Introduction

A major goal of nutritionists, dieticians and policy makers is to encourage greater consumption of dietary fibre. van der Kamp (2003), reporting on the Dietary Fibre 2003 conference, notes that it is still generally agreed that intakes of fibre and fibre-containing foods are well below recommended levels in Western countries, and advises that “the development of products that are attractive to consumers and underpinning research to this end is a key element in efforts to increase the intake of dietary fibre”. Cereal brans are a major category of dietary fibre and one that is particularly

beneficial in promoting gut health and avoiding a range of diseases (Mongeau and Brassard, 1982; Ferguson and Harris, 1997; Zhang and Moore, 1999; Cho *et al.*, 2004). A major field of research is therefore centred around the incorporation of cereal brans into cereal-based and other food products, in forms that are attractive to consumers, as the basis for encouraging healthy diets. However, cereal-based foods frequently derive their appeal from an aerated structure (Campbell, 2003), and bran is generally detrimental to the creation of aerated structures in these products. Understanding how bran interacts with bubbles in cereal-based foods is therefore fundamental to the effective development of healthy, fibre-rich versions.

The majority of the research activity in this area has focussed around bread, although as bread is highly aerated it is possibly not the ideal vehicle for delivering bran into the diet; several workers have therefore studied the incorporation of bran into less aerated products including cakes, biscuits, muffins, breakfast cereals, snack foods, flat breads and pizza (Pomeranz, 1977; Chen *et al.*, 1988; Sosulski and Wu, 1988; Basman and Köksel, 1999; Pacheco de Delahaye *et al.*, 2005). The effects of bran in bread (and to a lesser extent in these other products) are well established (with the details and extent of effects dependent on the type and level of bran incorporation): increased dough water absorption and loaf weight, decreased dough strength, increased dough stickiness, decreased mixing and fermentation tolerances, reduced loaf volume and specific volume, coarser crumb texture, darker crumb colour and reduced crumb softness (Shetlar and Lyman, 1944; Lorenz, 1976; Pomeranz *et al.*, 1977; Pomeranz, 1977; Dubois, 1978; Shogren *et al.*, 1981; Dreese and Hoseney, 1982; Rogers and Hoseney, 1982; Collins, 1983; Wootton and Sham-Ud-Din, 1986; Lai *et al.*, 1989a-c; Gan *et al.*, 1989, 1992, 1995; Rao and Rao, 1991; Zhang and Moore, 1997, 1999; Nelles *et al.*, 1998; de Kock *et al.*, 1999). Numerous sources of fibre have been studied in bread formulations, with wheat bran the most prevalent, followed by studies of oat bran. Generally, at equal levels of addition oat bran gives higher water absorption, stickier doughs and lower baked loaf volumes than wheat bran, but taste panellists tend to prefer the oat bran bread (D'Appolonia and Youngs, 1978; Krishnan *et al.*, 1987; Sosulski and Wu, 1988). White wheat yields whole grain bread products that are more acceptable to consumers than those made from red wheat (Marquart *et al.*, 2006). Bran from different wheat cultivars may produce bran with inherently less detrimental properties (Nelles *et al.*, 1998; de Kock *et al.*, 1999).

Addition of bran to bread dough formulations generally increases the level of water required; this additional water is retained by the loaf during baking, giving a heavier loaf and a lower specific volume (Dreese and Hoseney, 1982; Rao and Rao, 1991). Dreese and Hoseney (1982) and Rogers and Hoseney (1982), based on measurement of dough height during baking in an electrical resistance oven, argued that this water is also available for starch gelatinisation during baking, thereby lowering the starch gelatinisation temperature and, as a result, the extent of gas retention during baking (oven spring) and thereby the final loaf volume. This mechanism, if predominant, would imply that ultimately the effect of bran on gas retention is principally during baking, rather than earlier in the breadmaking process.

In addition, several workers have conceived bran to have a mechanical effect that physically disrupts gluten films, either during their formation in the mixer or, more probably, when they are stretched into thin films during the later stages of proving and early stages of baking (Shetlar and Lyman, 1944; Pomeranz *et al.*, 1977; Dubois, 1978; Wootton and Sham-Ud-Din, 1986; Gan *et al.*, 1989, 1992; Zhang and Moore, 1997). This postulation led Shetlar and Lyman (1944) to propose fine grinding of the bran to minimise this mechanical effect. This strategy proved effective, although possibly for reasons in addition to the mechanical effectiveness of the smaller particles, such as their increased rate of hydration (Lai *et al.*, 1989a). Gan *et al.* (1989, 1992) reported that pearling wheat kernels prior to milling improved the breadmaking performance of the resulting wholemeal flour, and identified epicarp hairs (which are preferentially removed by pearling) as being particularly deleterious to the mechanical integrity of the gluten films supporting the aerated loaf structure, concluding that this was due to a physical rupture, rather than a biochemical, mechanism. de Kock *et al.* (1999) considered the deleterious effects of bran in bread to have both physical and chemical causes.

It is perhaps implicitly assumed in many studies that bran damages the aerated structure when the expanded dough is at its most fragile, *i.e.* during the later stages of proving and early stages of baking. However the hypothesis that bran has effects on the gas phase during mixing or proving that directly contribute to the creation of the coarser crumb structure of bran-enriched breads has not been considered previously. It is widely believed that in no-time breadmaking processes the aerated structure created in the mixer directly affects the final baked loaf texture (Chamberlain and Collins, 1979; Cauvain *et al.*, 1999; Campbell, 2003); it is conceivable that bran could affect the initial air content and bubble size distribution and therefore affect baked loaf texture at least in part via this mechanism. Similarly, the growth of these bubbles depends on the mass transfer dynamics of CO₂ diffusion into the nitrogen nuclei initially created. This depends on the solubility and diffusivity of CO₂ in the liquid dough phase, as well as the initial bubble size distribution (Shah *et al.*, 1998; Chiotellis and Campbell, 2003a,b). Bran in the formulation could conceivably affect these and thereby slow bubble growth during proving, such that more of the CO₂ produced by the yeast is lost from the dough surface, giving less expansion and smaller loaf volumes.

The objective of the following work was therefore to investigate at which point during the breadmaking process (mixing, proving or baking) the addition of wheat or oat bran had its effect on the bubbles, as a basis for an interpretation of the effects of bran from the perspective of the gas bubble dynamics throughout breadmaking. In addition, more information on the effects of bran level and particle size in a no-time mechanical dough development system was sought.

2. Materials and Methods

2.1. Bran preparation

Commercial wheat bran (Flemings Bran Flakes, Champion Flour Mills, Christchurch, New Zealand) and oat bran (Harraways Oat Bran, Harraway and Sons Ltd., Dunedin, New Zealand) were purchased locally. The wheat bran had a nominal average dietary fibre content of 44% (37% insoluble and 7% soluble), while that for the oat bran was only 12.7%, and it was clear that the oat bran also contained a large proportion of oat flour. Oat bran is less easily defined than wheat bran because the starchy endosperm flour does not detach from the outer tissue layers so easily (Doehlert and Moore, 1997; Wood, 1997). In an attempt to increase the fibre content of the oat bran, 250 g samples were sieved over a 500 µm mesh screen for five minutes using a Simon rotary sifter (Henry Simon Ltd., Stockport, UK), with the material retained on the screen used in subsequent trials. Ash analysis of the original bran and of the throughs and overtails after sifting was performed in duplicate to confirm that sifting had increased the bran content of the retained material (AACC, 1995, Method 08-01). The oat bran had a median particle size, x_{50} , of 1050 µm prior to sifting, with 24.8% of the material smaller than 500 µm. Sifting the bran over 500 µm for 5 minutes removed 18.8% of the total material, an efficiency of 76%, and increased its median particle size to 1200 µm. The ash content of the original bran was determined to be 1.83%, and of the resulting throughs and overtails was 0.96 and 2.03%, respectively, indicating that the sifting strategy had removed mainly oat flour and had slightly increased the bran content of the remaining material.

Following the recommendations of Zhang and Moore (1997, 1999), identical bran samples were milled to obtain different size fractions of comparable composition. For the wheat bran, 30 g samples were milled for 0, 5, 10 and 30 seconds in a Bosch domestic coffee grinder. For the oat bran with the <500 µm material removed, 40 g samples were milled for 0, 5 and 30 s. The particle size distribution of the milled fractions was determined by sieve analysis using the Simon rotary sifter with Endecott sieves of aperture sizes 1700, 1000, 750, 500, 250 and 125 µm. Although not formally measured, the bulk density of the oat bran was clearly much greater than (over three times) that of the wheat bran. Milling the wheat bran increased its bulk density, while milling the oat bran decreased its bulk density, such that after 30 s milling both brans had similar bulk densities.

2.2. Dough preparation, baking and dynamic dough density measurements

Doughs based on 125 g of (flour + bran) were mixed in the MDD125 mixer as described in Chapter 32 (Campbell *et al.*, 2008a). Wheat bran fractions milled to different average particle sizes were substituted for flour at levels of 7.5 and 15%, while the less bran-rich oat bran fractions milled to different average particle sizes were substituted for flour at higher levels of 10, 20 and 30%. The optimum work input requirement and water absorption were determined for each bran size and level based on the measured torque during mixing, according to Crop and Food's in-house method B7. For baking trials the entire dough was recovered from the mixer and baked as described in Chapter 32 (Campbell *et al.*, 2008a). Duplicate loaves were prepared for each formulation (except for the loaves containing oat bran at 30%, for which only a single loaf was prepared for each size fraction). Arbitrary loaf volume was calculated as $(\text{volume in cm}^3 - 540)/18$. Texture was evaluated on a 1-11 scale by an experienced baker, and baking score calculated as the sum of the texture score and the arbitrary loaf volume, as described in Chapter 32. For dynamic dough density measurements, doughs were mixed with double the normal yeast level (*i.e.* 6% on flour weight instead of 3%, to increase the speed of the test) and with 1% less water than the optimum, to facilitate sample retrieval and handling. Immediately after mixing, the dough piece was gently sheeted, using a rolling pin and some rectangular Perspex rods, to a thickness of 12 mm. From this a sample was taken using a 21 mm diameter metal cookie cutter, and gently swirled in a spherical flask to strengthen the outer surface (Campbell *et al.*, 2008a). The sample was then tested using the dynamic dough density (DDD) approach described previously (Campbell *et al.*, 2001; Chiotellis and Campbell, 2003b; Campbell *et al.*, 2008a). Two DDD systems were used as described by Campbell *et al.* (2008a). For each trial, doughs were mixed in a random order and processed alternately through the two systems, then duplicate doughs were mixed in the reverse random order and again processed alternately, such that each dough treatment was evaluated using both DDD systems, to avoid any systematic error arising from differences between the two systems. In addition, doughs were mixed without yeast and the density measured, to indicate the effect of bran source, level and particle size on the aeration of the doughs during mixing.

3. Results and Discussion

In the following discussion, it is recognised that the differences between wheat and oat bran are substantial and diverse, oat bran containing more endosperm than wheat bran (as noted above), being richer in β -glucans and lipids, and differing from wheat bran in terms of composition and thermo-mechanical properties in more or less every respect. The intention of the following work is not to attempt to explain the differences in behaviour of the particular wheat and oat bran samples used in the current study, nor to imply that these particular samples are necessarily representative of all wheat or all oat bran samples (although the findings are broadly consistent with comparable studies). The purpose is, rather, to use these starkly contrasting but generally well studied bran types to demonstrate that in a general sense bran interacts with bubbles throughout the breadmaking process, and that the details of the interaction depend on the source and nature of the bran.

3.1. Effects of bran level and particle size on work input and water absorption during mixing

Figure 1 shows the cumulative particle size distributions of wheat and oat bran samples milled for different times in the coffee grinder. Clearly, particle size decreased significantly even with short milling times. The particle size below which 50% of the material fell (the mass-based median, x_{50}) was determined by linear interpolation to be 1570, 940, 740 and 520 μm for the wheat bran samples milled for 0, 5, 10 and 30 s, respectively, and 1200, 540 and 230 μm for the oat bran samples milled for 0, 5 and 30 s, respectively.

Doughs were prepared containing wheat bran substituted for flour at levels of 7.5 or 15%, or oat bran at levels of 10, 20 or 30%, along with control doughs with no bran. Table 1 lists the optimum work inputs and water absorptions measured for the various dough formulations. Each result is based on two or three replicate measurements, except the oat bran milled for 30 s, for which the data are from a single determination. Based on long experience with these mixers, differences of greater than 1 Wh/kg or 1% water absorption are considered significant. The work input and water absorption of the original flour were 12.9 Wh/kg and 61.5%, respectively. The addition of wheat bran at 7.5% reduced the optimum work input to an average of 11.1 Wh/kg, and increased the water absorption to 65.7%. Addition of wheat bran at 15% gave essentially the same optimum work input

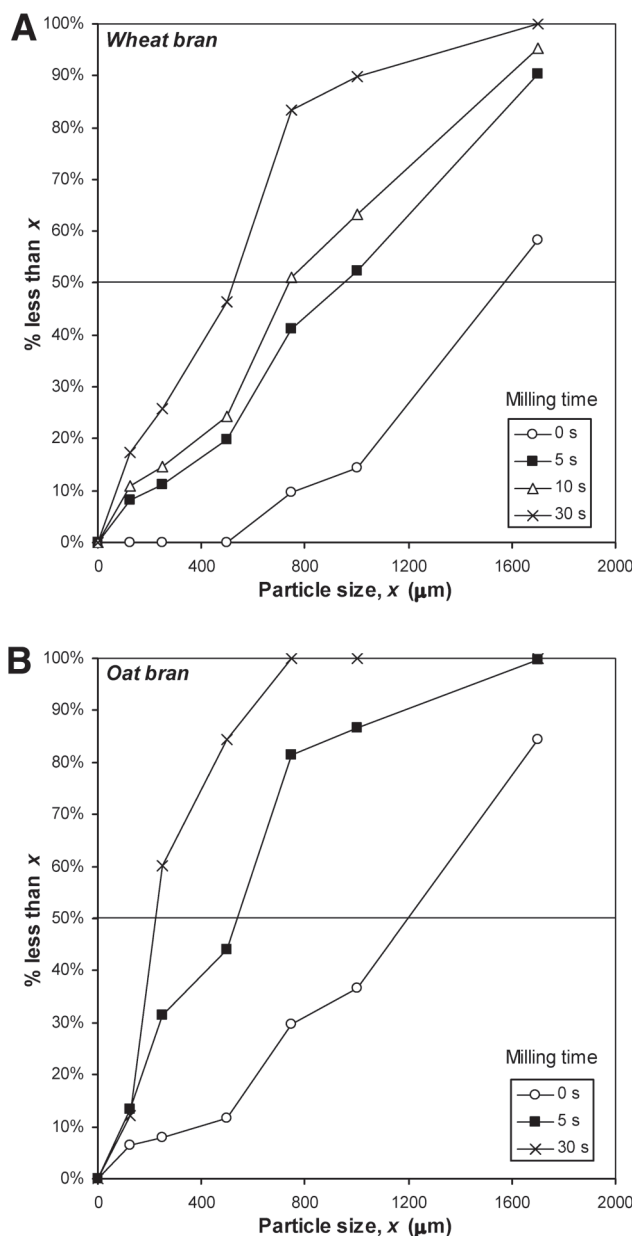


Figure 1. Cumulative particle size distributions from (a) wheat bran and (b) oat bran milled in a coffee grinder for different times.

(11.3 Wh/kg), and further increased the water absorption to an average of 69.5%. At both levels particle size had only a weak effect, consistent with Zhang and Moore (1997) and with Lorenz's (1976) finding for triticale bran. By contrast, the effect of the addition of oat bran depended strongly on the particle size. As with the wheat bran, oat bran reduced the optimum work input and increased the water absorption, with the magnitude of the effect increasing with the level of bran addition. However, smaller oat particles gave much larger effects. The observations of Cadden (1987, 1988) regarding the different responses of wheat and oat bran to milling are consistent with these observations; the increased surface area of the oat bran following milling allows more rapid uptake of water during the short mixing time, while for the wheat bran this is offset by the destruction of water-retaining structures in the bran. The effects on water absorption found in the current work also agree with those of Krishnan *et al.* (1987).

3.2. Effects of bran level and particle size on aeration during mixing

Figure 2 shows the densities of unyeasted doughs containing wheat or oat bran of different sizes and at different levels. (Throughout this paper error bars, where shown, are ± 1 standard deviation of the mean, based on a pooled standard deviation. In this figure example error bars are shown for one data set only, to maintain clarity of the figure.) (The doughs containing wheat bran were mixed to the same work input of 11.2 Wh/kg (the average of the results reported in Table 1) for all the size fractions, and to water absorptions of 64.7 and 68.4%, 1% less than the average of the values reported in Table 1, in order to facilitate sample retrieval and handling. The doughs containing oat bran were mixed to the optimum work inputs indicated in Table 1 for each level and particle size, and with 1% less water than indicated.) Clearly addition of bran reduced the density of the doughs. For the wheat bran, addition at 7.5% reduced the density from 1.135 g/cm³ for the dough with no bran to an average value of 1.121 g/cm³, and addition at 15% decreased the density further, to an average value of 1.105 g/cm³; however, particle size had little effect. For the oat bran, all lev-

Table 1. Optimum work inputs and water absorptions measured for dough formulations containing wheat and oat bran.

		Work Input (Wh/kg)						
		Wheat Bran			Oat Bran			
No bran	Milling time (s)	Particle size (μm)	7.5%	15%	Particle size (μm)	10%	20%	30%
12.9	0	1570	12.2	11.8	1200	11.95	9.90	8.40
	5	940	10.8	11.4	540	10.65	9.00	7.60
	10	740	10.8	11.3	–	–	–	–
	30	520	10.8	10.7	230	9.15	8.25	6.50
		Water Absorption (%)						
		Wheat Bran			Oat Bran			
No bran	Milling time (s)	Particle size (μm)	7.5%	15%	Particle size (μm)	10%	20%	30%
61.5	0	1570	65.4	69.9	1200	62.1	62.9	61.1
	5	940	65.7	69.6	540	63.7	64.3	63.4
	10	740	66.1	69.3	–	–	–	–
	30	520	65.7	69.0	230	65.6	66.1	66.4

els of addition decreased the density, but unlike the wheat bran results, the extent of the reduction was not in proportion to the level of addition. Again particle size had no strong or consistent effect.

Dough density depends on the extent of aeration of the dough and on the gas-free dough density, both of which vary with the work input and the amount of water in the formulation (Campbell *et al.*, 1993; Chin and Campbell, 2005). The major effect of bran is to increase the water absorption, which decreases the gas-free density of the dough. Thus for the wheat bran, particle size had little effect on the work input, the water absorption or the dough density, while the level of addition affected the latter two; the observed reduction in dough density on adding bran to the formulation is in part due the reduction in the gas-free dough density resulting from the increased water addition. Campbell *et al.* (2008b) in Chapter 34 investigate the effect of wheat bran on dough aeration in more detail, concluding that the wheat bran used in that work increased dough aeration during mixing, and that large particles increased aeration more than small particles. For the oat bran, particle size and level of addition greatly affected work input and water absorption, but not dough density. This implies that the increased water content of doughs with finely ground bran, which would decrease density, was offset by a factor acting to increase density, possibly a reduction in gas content with smaller particles. A comprehensive study would be needed to untangle the relative contributions of these interacting factors; however, it appears that the addition of oat bran does not give dramatic changes in dough density indicative of substantial differences in the level of aeration of the dough achieved in the mixer. However it is possible that the presence of bran particles alters the rate of turnover of air during mixing, while leaving the gas content relatively unchanged; this is investigated by Campbell *et al.* (2008b) in Chapter 34.

Inclusion of bran could also affect the bubble size distribution in the dough. This, independently or in combination with a change in the air content, could change the interfacial area available for mass transfer of CO₂ into bubbles and hence the rate of growth of the dough piece, particularly during the early stages of proving. Figure 3 illustrates the density profiles obtained using the finest wheat bran and the medium oat bran, which had similar median particle sizes, at different levels;

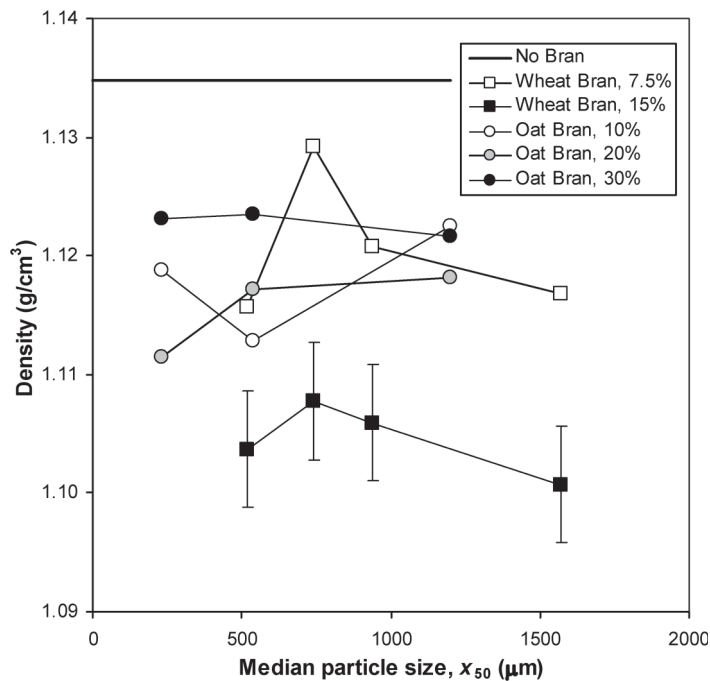


Figure 2. Effect of level of addition and particle size on densities of unyeasted doughs containing wheat or oat bran.

similar results were obtained from the other bran samples. There is no evidence of significant differences in the profiles at the early stages of proving, particularly for the oat bran. This supports the view that the effect of adding bran is not mediated through changes to the aerated state of the dough *ex-mixer* (but see Campbell *et al.*, 2008b, in the next chapter, which examines the effect of wheat bran particle size on aeration during mixing in more detail).

3.3. Effects of bran level and particle size on dynamic dough density profiles and maximum expansion

Campbell *et al.* (2008a) report that addition of wheat bran at 7.5% slightly increased the maximum expansion of the dough during proving, as measured by the DDD technique, compared with a control with no bran. However this did not persist during baking, such that addition of 7.5% bran decreased the final loaf volume. Addition of 15% bran gave much the same DDD expansion as the control, but resulted in a much lower baked loaf volume.

Figure 3 confirms that the wheat bran had relatively little effect on dough expansion, in marked contrast to the oat bran which drastically reduced the maximum expansion of the doughs. Figure 4 clarifies this further, plotting the maximum expansion ($1/\rho_{\min}$, the inverse of the minimum density) versus median particle size for the two brans at different levels of substitution. As found previously (Campbell *et al.*, 2008a), Figure 4 shows that the wheat bran at 7.5% slightly increased dough expansion, with 15% returning expansion to levels similar to the control doughs. These results are consistent with those shown in Figures 3(b) and 6 of Campbell *et al.* (2008a), although less pronounced, possibly due to the effect of mixing the doughs with 1% less water. These results suggest that addition of bran at a level of 7.5% had the effect of making the dough slightly more extensible, enhancing its ability to retain gas during proving, but that addition at 15% removed the effect. It has been noted in the literature that bran appears to have two counteracting effects when added to bread, one beneficial, the other deleterious (Shetlar and Lyman, 1944; Wootton and Sham-Ud-Din, 1986). This probably accounts for some of the contradictory effects reported in the literature, and possibly also contributes to the effect observed here, that at low levels of substitution, bran appears slightly beneficial to gas retention during proving, but not at higher levels.

Surprisingly, the particle size of the wheat bran had no distinguishable effect on maximum expansion. This correlates with the finding above, that wheat bran particle size also had no effect on optimum water absorption (based on mixer torque) or work input. It implies that the effects of bran on dough expansion may be related to the effects of bran on water absorption and/or dough development—particle size did not affect either of these, for the reasons discussed above, and did not affect dough expansion, possibly for the same reasons.

By contrast, oat bran reduced maximum expansion in proportion to the level of inclusion. In this case, as with work input and water absorption, and again in contrast with the wheat bran results, particle size had a major effect. This was more evident at higher levels of oat bran, for which coarser particles allowed greater expansion than finer particles. These results indicate that addition of the oat bran had a large part of its effects, in relation both to level of addition and to particle size, during proving, in contrast to the wheat bran for which the major effect appeared to occur during baking. Again, the correlation with water absorption and optimum work input results implies that the effects of bran on expansion originate with its effects on these parameters.

3.4. Effects of bran level and particle size on baked loaves

Figure 5 shows the effect of wheat and oat bran particle size and level on baked loaf volumes. In this case the addition of both bran types was detrimental to loaf volume at all levels of substitution. Any enhancing effect of the wheat bran at the 7.5% level during proving was lost during baking. Oat bran gave greater reductions in loaf volume than wheat bran (acknowledging that the levels of substitution are greater for oat bran, but also that its actual bran content is less—part of the effect

of the oat bran arises from the dilution of wheat flour with oat flour, in addition to the effects of the oat bran itself).

For both bran types there appears to be a consistent effect of particle size, with larger bran particles giving slightly larger loaves, but the effect of particle size is less dramatic than that of level of bran incorporation. However, comparing Figures 4 and 5, there appears to be little correlation between maximum expansion as measured by DDD and baked loaf volume for the wheat bran doughs, but very similar patterns for maximum expansion and baked loaf volume for the oat bran doughs. Figure 6 confirms this by plotting specific loaf volume versus maximum dough specific

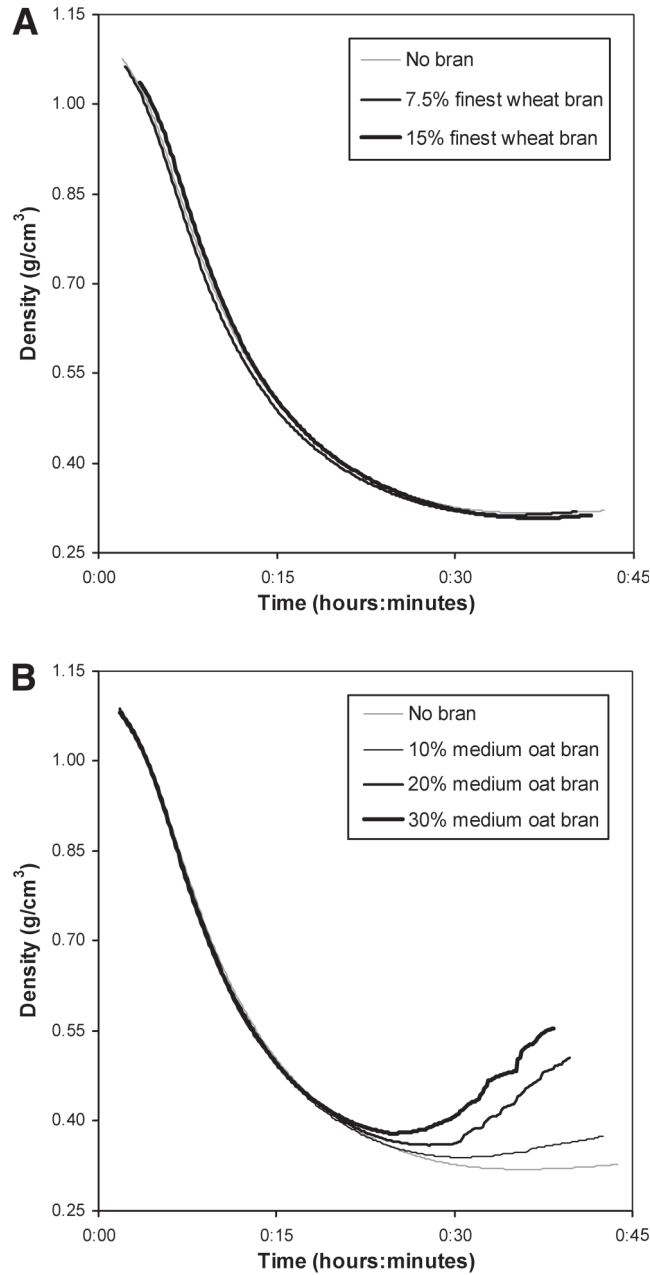


Figure 3. Effect of (a) finest wheat bran ($x_{50} = 520 \mu\text{m}$); and (b) fine oat bran ($x_{50} = 540 \mu\text{m}$) incorporation on dynamic density profile.

volume (both in units of cm^3/g) for both wheat and oat bran doughs. For the wheat bran doughs, there is no clear correlation, although if the control dough with no bran were excluded a weak correlation might be suggested. For the oat bran doughs, by contrast, there is a strong and statistically significant correlation between baked loaf specific volume and maximum dough specific volume.

The poor correlation between expansion during proving, as measured by the DDD technique, and baked loaf volume for doughs containing wheat bran implies that the negative effects of wheat bran on bread occur during baking, not during proving. Indeed, during proving, wheat bran at low levels (7.5%) appears to have a slight strengthening effect, allowing slightly greater expansion. However, this is not preserved during baking, such that baked loaves containing 7.5% wheat bran are of smaller volume than control doughs. From this it is concluded that the effects of wheat bran on bread quality are manifest principally during baking rather than during proving. This is in agreement with the hypothesis of Dreese and Hosney (1982) and Rogers and Hosney (1982), that the extra water required in a dough formulation containing bran is available for starch gelatinisation during baking, thereby lowering the setting temperature and hence the oven spring during baking and the final loaf volume.

By contrast, the good correlation between DDD expansion and baked loaf volume for the oat bran breads implies that oat bran exerts its negative effects principally during proving, rather than during baking; the depression of expansion during proving is preserved by baking and evident in the final loaves.

Table 2 summarises the weight, texture, volume and baking scores for the wheat and oat bran loaves. (The wheat and oat bran work was carried out in different weeks, with duplicate controls containing no bran prepared each time; the results for no bran are averaged from the controls for the separate wheat and oat bran experiments.) The amount of water in the various formulations was reflected in the loaf weights; this indicates that the additional water required when bran is included is retained during baking, in agreement with Dreese and Hosney (1982) and Rao and Rao (1991). With increased bran substitution, the external appearance of the loaves became coarser, with flakes of bran visible in the crust. Grinding the bran gave a smoother but duller appearance that was con-

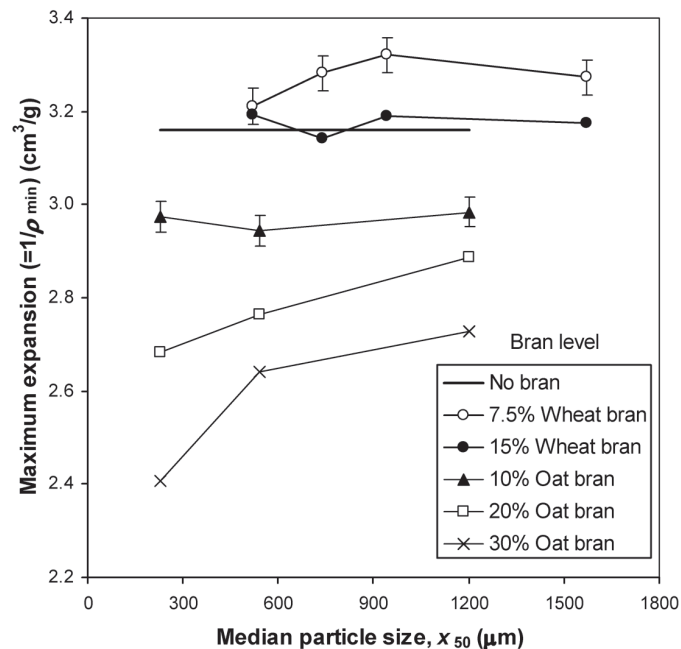


Figure 4. Effect of wheat bran and oat bran particle size and level on the maximum expansion of the dough during proving.

sidered less attractive. Strength of the crumb decreased with increased level of incorporation and with grinding; the loaf containing 30% oat bran ground for 30 s was particularly fragile and broke easily when handled. This is evident in Figure 7, which illustrates the effect of the coarse and fine oat bran samples on loaf volume and texture. Increased levels and grinding of bran gave cells with thick walls, elongated horizontally instead of vertically and more compressed in the lower part of the loaf, and a darker crumb colour.

For both the wheat and the oat bran, finer particles gave smaller loaf volumes, but greatly improved the fineness of the crumb texture (although for the oat bran loaves this is not reflected strongly in the texture scores in Table 2, owing to negative effects on other aspects of crumb texture such as cell wall thickness and cell elongation). Close examination of Figure 7 illustrates this for

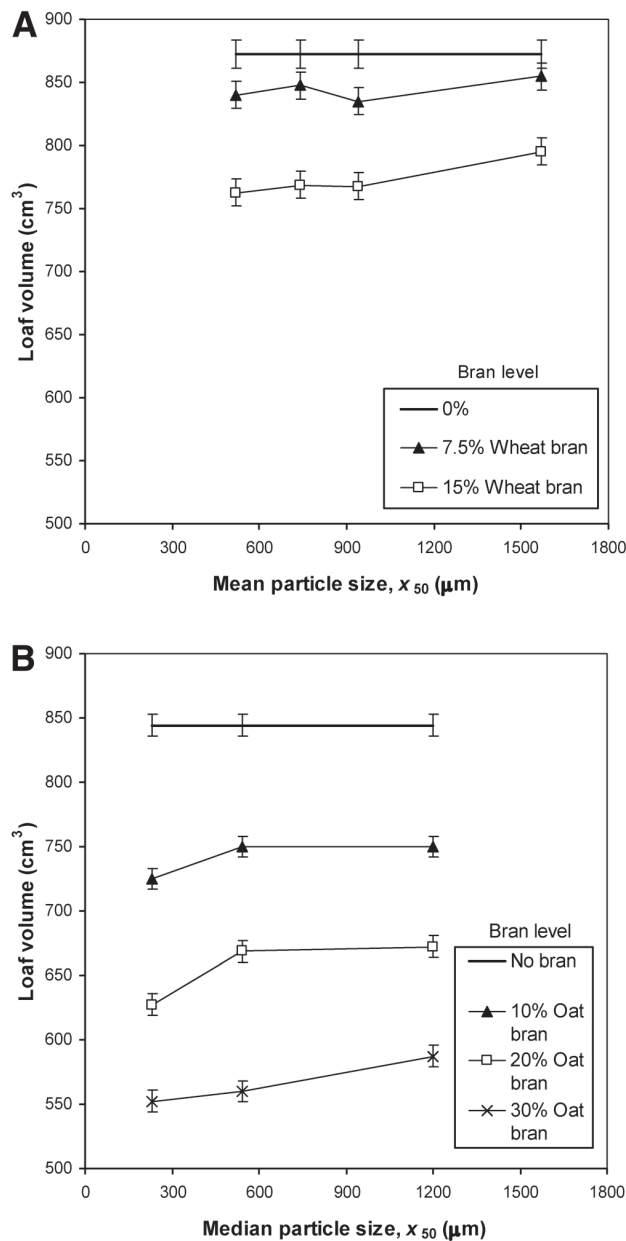


Figure 5. Effect of (a) wheat bran and (b) oat bran particle size and level on baked loaf volumes.

the loaves baked with coarse and fine oat bran; the latter have a noticeably finer crumb structure. Figure 8 illustrates the same effect for wheat bran, in which the finest wheat bran particles gave a finer crumb texture than the coarsest wheat bran. Collins (1983), Collins *et al.* (1985) and Collins and Young (1986) similarly reported that fine wheat bran gave a denser looking, closer crumb and smaller loaf volumes than medium or coarse brans. de Kock *et al.* (1999) found that smaller bran particles gave lower loaf volumes and more dense crumb structures (although their samples varying in size were obtained from different milling streams, rather than from milling initially identical samples, so differed in chemical composition as well as size). Lorenz (1976) also found that breads

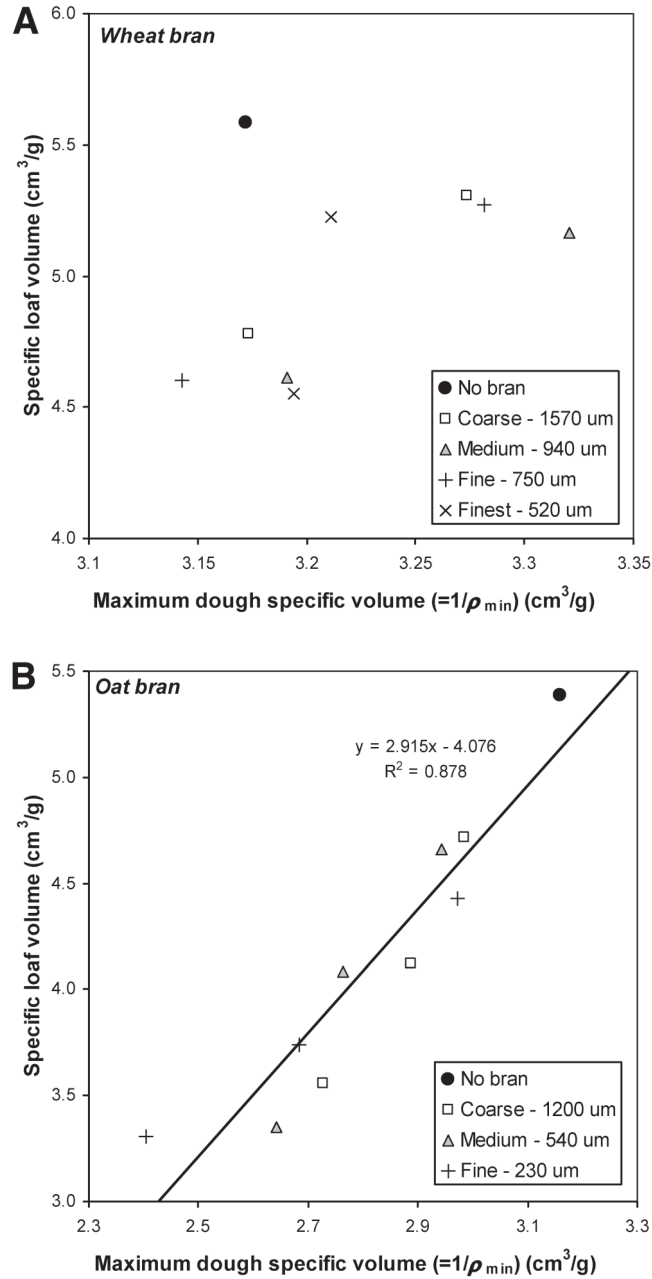


Figure 6. Specific loaf volume versus maximum DDD expansion for doughs containing (a) wheat bran and (b) oat bran at various levels and particle sizes.

baked with fine triticale bran were softer and had a more uniform grain and smoother texture than those baked with coarse bran, but gave essentially no difference in loaf volume.

The results for oat bran are in agreement with those of Krishnan *et al.* (1987) who found coarse oat bran to be less deleterious to loaf volume than fine oat bran, although these were from

Table 2. Loaf weight, texture, volume and baking scores for loaves prepared with different levels and particle sizes of wheat or oat bran. Differences in texture or baking score of 1 are considered significant. For loaf volumes, the standard error of the mean of two replicates was 11 cm³ for the wheat bran loaves and 6 cm³ for the oat bran loaves.

Loaf weight (g)						
Milling time (s)	Wheat Bran			Oat Bran		
	No bran	7.5%	15%	10%	20%	30%
0	156.4	161.1	166.3	159.0	163.3	165.2
5		161.6	166.8	160.9	163.8	167.0
10		160.7	167.0	–	–	–
30		160.7	167.5	163.7	167.7	167.1

Texture (1-11)						
Milling time (s)	Wheat Bran			Oat Bran		
	No bran	7.5%	15%	10%	20%	30%
0	8.8	4.5	3.5	6.75	5	2
5		5.0	5.0	6	4.5	2
10		6.5	5.0	–	–	–
30		6.75	4.75	7	4.5	1

Volume (cm ³)						
Milling time (s)	Wheat Bran			Oat Bran		
	No bran	7.5%	15%	10%	20%	30%
0	858	855	795	750	673	588
5		835	768	750	669	560
10		848	769	–	–	–
30		840	763	725	628	553

Baking score						
Milling time (s)	Wheat Bran			Oat Bran		
	No bran	7.5%	15%	10%	20%	30%
0	26.5	22.5	17.7	18.4	12.3	4.6
5		21.3	17.5	17.6	11.6	3.1
10		23.5	17.5	–	–	–
30		23.3	17.0	17.2	9.3	1.7

samples that were sifted rather than milled in order to achieve the different particle sizes, so could have varied in composition as well as size. They also reported that a taste panel preferred 15% oat bran breads made with large particles and 10% bran levels made with intermediate particles, while the 15% small bran bread was consistently scored the lowest in all sensory aspects.

The literature frequently advises grinding bran in order to alleviate its adverse effects on bread quality (Shetlar and Lyman, 1944; Pomeranz, 1977; Moder *et al.*, 1984; Lai *et al.*, 1989a), although smaller bran particles can be less beneficial physiologically (Mongeau and Brassard, 1982; Cad-den, 1987, 1988; Ferguson and Harris, 1997). The results presented here indicate that grinding both wheat and oat bran results in smaller loaves but with a finer texture. Zhang and Moore (1999) similarly found that smaller wheat bran particles gave a finer texture, but that intermediate particles gave the largest specific loaf volume. Their “Fine” bran had a mean particle size of 278 μm , much smaller than the finest sample used in the current work, while their “Medium” sample had a mean particle size of 415 μm , similar to the finest wheat bran sample used in the current work. Reconciling the effects of bran particle size on these two aspects of baked loaf quality, in order to advise bakers more precisely, requires a more profound and detailed insight into the interaction of bran with bubbles, including studies over a wider range of bran particle sizes and with a greater number of bran samples of differing natures and origins.

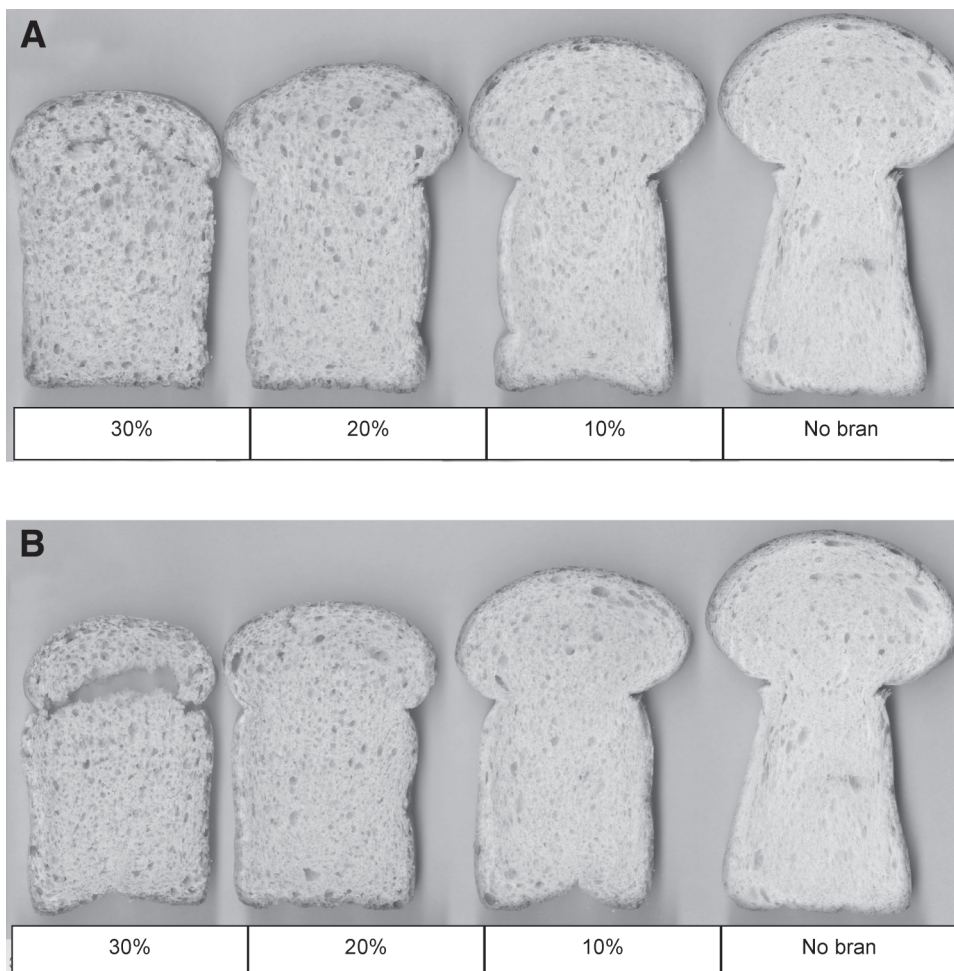


Figure 7. Cross sections of loaves prepared from doughs mixed with (a) coarse ($x_{50} = 1200 \mu\text{m}$) and (b) fine ($x_{50} = 230 \mu\text{m}$) oat bran at different levels of substitution.

Previous studies on bran in bread have tended to focus on the chemical species and physical factors causing the deleterious effects. Few studies have attempted to identify *when* in the bread-making process bran exerts its effects, with the notable exceptions of Dreese and Hosenev (1982) and Rogers and Hosenev (1982) who, based on results from an electrical resistance oven, considered that the consequences of wheat bran addition were manifest during baking. (Observed effects on mixing time and water absorption do not imply that the adverse effect of bran on loaf volume and crumb structure occurs during mixing; the water added at that point and the degree of development achieved in the mixer affect the process at later stages.) Conversely, Collins (1983) noted “One problem with brown and wholemeal doughs concerns their reluctance to hold gas and expand to full proof. The gas produced tends to escape towards the end of final proof as the gas bubbles in the dough rupture... Adding DATEM esters or other emulsifiers such as sodium stearyl lactylate, aids gas retention in proof and influences loaf volume and the uniformity of crumb structure”. Galliard and Collins (1988) similarly noted the susceptibility of wholemeal doughs in commercial production to collapse during the later stages of proving as well as the early stages of baking, although they attributed the effectiveness of DATEM in wholemeal formulations to its contribution to baking expansion. Rasco *et al.* (1991) found with some of their bran pretreatments that loaf volume and proof height appeared to be equally affected. Most studies have reported baked loaf volumes but have omitted to collect information about the dough expansion during proving. The results presented here tend to support the view that the major effect occurs during baking with respect to the wheat bran, but not with respect to the oat bran, which appears to give noticeable effects during proving. However the DDD technique employed here, while very sensitive, is also very gentle with the dough and avoids the shocks encountered in commercial practice that may underlie the observations of Galliard and Collins (1988). It is also acknowledged that the work presented here is based on a single sample each of commercial wheat and oat bran; each of these will not be representative of all brans from these cereals, which can exhibit substantial differences in chemical composition and physical structure resulting from differences in origin and processing. However, despite these qualifiers, the results presented here appear to be consistent with other comparable studies.

The behaviour of bran in bread is extremely complex, and it is difficult to disentangle the often highly correlated phenomena into causes and effects. For example, addition of oat bran strongly affected work input and water absorption; are the later observations of dough expansion



Figure 8. Cross sections of loaves prepared from doughs mixed with coarse (left, $x_{50} = 1570 \mu\text{m}$) and finest (right, $x_{50} = 520 \mu\text{m}$) wheat bran at 7.5% substitution.

and baked loaf quality direct effects of the bran or artefacts of the altered dough formulation and development? Much more detailed studies are required to address this and other questions in order to manage bran in bread more profitably. Nevertheless, the current work, by focussing on the gas phase behaviour, has demonstrated that brans can exert their effects through mechanisms that are qualitatively different, not just in degree. Recognising that different fibre sources interact with the bread structure via different mechanisms will help to avoid an ineffective and costly “one size fits all” approach to countering the adverse effects of fibre in breadmaking.

4. Conclusions

Addition of wheat or oat bran to dough formulations appeared to have counteracting effects on dough density *ex-mixer*, the untangling of which requires further studies. Wheat bran decreased the optimum work input and increased the water absorption, with particle size having little effect. Wheat bran added at 7.5% slightly increased the expansion of the dough during proving, but nevertheless gave a lower loaf volume, while at 15% the bran had little effect on expansion during proving but greatly affected baked loaf volume. Particle size did not affect expansion during proving, but coarser particles gave larger loaf volumes than finer particles, but also gave more open textures. The poor correlation between the proving and baking results argues that the wheat bran had its major effects on the aerated structure during baking rather than earlier in the breadmaking process. The effects of oat bran, however, contrasted with those of the wheat bran in several respects. For the oat bran, the particle size had substantial effects on the optimum work input and water absorption of the doughs. As with the wheat bran, larger oat bran particles gave larger loaves than did finer particles, but with coarser crumb textures. In contrast with the wheat bran, both the level and particle size of the oat bran affected expansion during proving, resulting in a strong correlation between proving expansion and baked loaf volume. The results argue that the mechanisms by which bran damaged bread structure and texture were different for the wheat and the oat bran samples investigated, with the wheat bran exerting its effects principally during baking, while the oat bran mainly affected gas retention during the later stages of proving.

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