



Effect of supplementation of wheat bran on dough aeration and final bread volume

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11 **Abstract**

12 One of the best ways to increase the fiber content in the diet is supplementing wheat
13 bran in bread. Wheat bran is known to affect the cellular structure of the dough, resulting in
14 lower final bread volume. The present study was focused on analyzing the effect of wheat
15 bran in throughout the bread making process; the results were compared with the recipe
16 without bran. Wheat bran at different level viz., 0%, 8 %, 16% and 24% w/w on flour basis
17 was added into the wheat flour for the preparation of sandwich bread. Results showed that
18 wheat bran significantly ($p<0.05$) affected the dough kneading parameters. Dough properties
19 like stickiness and extensibility decreased with respect to increase in bran quantity.
20 Unexpectedly, wheat bran enhanced the aeration of dough during mixing and the expansion
21 rate of dough during fermentation. However, wheat bran decreased the specific volume of
22 bread upto 10.81%, which was confirmed using 2D image analysis method where it was
23 observed as the wheat bran alters the pore size distribution in bread crumb.

24 **Keywords:** wheat bran, kneading, rheology, expansion rate, pore size

25 **1. Introduction**

26 Wheat bran is rich in fiber and is an important source of fiber for diet and nutritional
27 concerns. Increased intake of dietary fiber plays beneficial role in the reduction of chronic
28 diet related disorders namely cardiovascular disease, obesity, diabetes, colorectal cancer and
29 constipation (Lairon et al., 2005; Rodriguez et al., 2006). In the last two decades, consumers
30 started to prefer dietary fiber rich foods due to its health benefits (Drzikova et al., 2005).
31 Wheat is the most commonly available cereal crop in the world and wheat bran is the major
32 by-product from the wheat industry. Generally, white bread prepared from refined wheat
33 flour is consumed in western countries which leads to reduced intake of dietary fiber. The
34 main aim of supplementing wheat bran in bread is to meet the consumer demand, in order to
35 increase the dietary fiber level in bread. Addition of wheat bran considerably affected the
36 dough properties and final bread qualities (Ognean et al., 2006). Therefore, it is necessary to
37 analyse the effect of wheat bran on dough and bread.

38 Bread is considered as one of the oldest processed food. Each ingredient used in bread
39 has its own function throughout the bread making process and also it enhances the quality
40 such as freshness, softness and mouth feel of the final product. Therefore, a proper balance of
41 ingredients should be acquired to produce high-quality bread (Giannou et al., 2003). Bread

42 making can be divided into three main stages namely kneading, fermentation and baking.
43 During mixing and kneading, mechanical energy is applied to convert flour mixture and
44 water into a homogenous viscoelastic dough. Effect of fiber in the properties of dough and
45 bread mainly depends on the particle size, composition and amount of fiber added
46 (Ktenioudaki & Gallagher, 2012). Banu et al. (2012) found that different w/w concentration
47 (i.e., 3% to 30%) of wheat bran significantly affected the rheological properties of dough. It
48 has been concluded that refined wheat flour with 25% wheat bran has higher nutritional value
49 with ash content similar to whole wheat flour and causes minimum damage to the bread
50 quality.

51 Calderon-Dominguez et al., (2004) noted that the mixing time and temperature
52 affected the dough extensible characteristics. The air bubbles incorporated into the dough
53 during mixing acts as a nucleation site during proving. However, at the time of fermentation
54 these bubbles will get inflated with carbon dioxide which gives foam like aerated structure to
55 the dough (Bloksma, 1990). The final loaf volume and bread texture depends on the stability
56 and growth of these bubbles (Sliwinski et al., 2004). The two basic mechanisms involved in
57 the bubble destabilization during proving are disproportionation and coalescence.
58 Disproportionation is the process of migration of carbon dioxide present in the smaller
59 bubbles to larger bubbles due to Laplace pressure difference whereas coalescence is caused
60 by the rupture of thin dough films which leads to gas loss and formation of irregular and
61 coarse crumb structure (Kokelaar & Prins, 1995).

62 The dough expansion (Zhang et al., 2007) and gas retention capacity (Gomez et al.,
63 2003) during fermentation depends on the rheological properties such as elasticity and
64 viscosity of the cell membrane in the dough. Both physical and chemical mechanism of
65 wheat bran involved in affecting the properties of gluten network. The interaction between
66 gluten and fiber prevented free expansion of dough during fermentation (Ragaei et al., 2011).
67 Different level of wheat bran in the dough affected gluten re-aggregation during mixing. This
68 lead to coalescence or disproportionation of the gas cells during fermentation and, hence,
69 resulted in reduced gas retention in the dough. It has been proposed to use coarse bran rather
70 than fine bran because the interaction between fine bran and gluten was more which
71 adversely affected the gluten network (Noort et al., 2010). Zhou et al. (2004) and Li et al.
72 (2012) believed that arabinoxylan gels, formed through oxidative gelation of ferulic acid,
73 affected the gluten network and resulted in lower baking quality of bread. Zhang and Moore

(1999) evidenced that bread with medium particle sized wheat bran (mean particle size 415 μm) had significantly higher specific volume than bread with coarse (609 μm) or fine (278 μm) bran.

Baking is the most important part of bread making process which converts dough into bread by applying heat (Khater and Bahnasawy, 2014). Major role of baking is to alter the sensory properties of foods and to destroy enzymes and microorganisms (Fellows, 2000). While baking, fiber directly interacted with the structural elements of the three dimensional gluten networks and ruptured the starch–gluten matrix resulting in the interconnection of adjacent gas cells (Gan et al., 1995). Generally, wheat bran is rich in α -amylase, which directly causes damage to the gluten network and indirectly to the baking quality with the loss of crumb texture and loaf volume (Every et al., 2002). When the level of extruded wheat bran increased from 15% to 20% (w/w) in bread, the final volume of bread as well as porosity was decreased (Basinskiene et al., 2008). The specific volume of the bread decreased and in turn the density may increase from 0% to 40% depending on the bran type and level of bran added in the recipe as indicated by (Katina et al., 2010). Incorporating fermented wheat bran in bread formulation significantly reduced 20% of the bread's specific volume and also affected the physical and sensory properties of baked bread (Hassan et al., 2008). This study aims to assess the effect of adding different levels (w/w) of wheat bran viz., 8%, 16% and 24% to the sandwich bread. It helps to optimize the formulation by understanding the effect of wheat bran on dough porosity at the end of mixing and kneading process and final bread volume.

95

2. Materials and Methods

2.1 Raw materials

The wheat flour used for this study T65 (0.62%-0.65% ash content (Whitley, 2006)) was provided by Minoterie Girardeau, France. Other ingredients such as wheat bran, water, salt (Les Salins du Midi - France), sugar (Beghin Say - France), purple ibis (bread flour improver, Lesaffre - France), soybean flour (Giraud - France), milk powder (skimmed milk-Regilait, France), dry yeast (Saf instant, Lesaffre - France) and colza oil (Transgourmet, France) were also added in order to increase the taste and final quality of bread. The formulation protocol of sandwich bread was given in Table 1.

Generally, most of fibrous materials are hydrophilic in nature. An increased level of pentosans in fiber leads to higher water absorption property (Hoseney, 1984). Rosell et al. (2001) stated that the water binding capacity of fiber enriched dough is higher, because, more number of hydroxyl groups present in the fiber structure permits to hold higher amount of water through hydrogen bonds. Therefore, the water required to hydrate the mixture increased with increase in the level of wheat bran added in the recipe. Thus, the amount of water required to be added in the mixture with respect to wheat bran was determined by using the the following formula.

$$\Delta Hydration = \frac{(Mass\ of\ water\ with\ bran - Mass\ of\ water\ without\ bran)}{(Mass\ of\ bran)} \quad (1)$$

Where, $\Delta Hydration = 1.041$

The delta hydration coefficient value (1.014) was determined by making DSC tests on the free (freezable) water, in order to keep it constant when wheat brans were added to the dough.

LOCATION OF TABLE 1

2.2 Dough preparation and bread making procedure

The water temperature was adjusted in such a way that the cumulative sum of the temperature of flour, ambience and water should be equal to 50°C. Prototype planetary spiral mixer (VMI, Montaigu Vendee, France) was used to knead the dough. There were two different stages carried out during dough mixing: slow speed mixing (50 RPM for the gyratory motion of the spiral hook and 6 RPM for the rotational motion of the mixer's bowl) for 5 min followed by fast speed mixing (120 RPM for the gyratory motion of the spiral hook and 10 RPM for the rotational motion of the mixer's bowl) for 5.35 min. The temperature inside the bowl of the planetary mixer was maintained by cooling water which was supplied by the heat exchanger fixed inside the mixing system. The bowl temperature was fixed as 20°C, to maintain uniform dough temperature at the end of mixing. The power required to mix the dough and dough temperature with respect to mixing time were recorded automatically. The dough development time was determined by overmixing the dough. The optimum time required to develop the dough was found by plotting the graph between dough mixing time and maximum power consumed by mixer during mixing. The optimum mixing time of the dough varied with amount of bran added to the recipe. After mixing, bulk of the

dough was divided into small pieces of 560 g (weight determined according to the final weight of bread) and shaped into balls. Then, the shaped dough was allowed to rest for 20 min. This rested dough was sheeted and moulded into rolls by passing through the dough moulder (Deleume L'Artisane® 2004 AVE.BP, Saint-Eloi, France) in order to maintain uniform size and shape of dough, by fixing constant roller speed of 208 RPM and roller gap of 2.8 mm. The moulded dough was fermented (Hengel AR68, Parigny, France) at a temperature of 37°C and 80% relative humidity. Finally, the fermented dough was baked in oven (MIWE CO 1.1208, Germany) at a temperature of 220°C for 20 min.

2.3 Wheat bran particle size analysis

A Laser Diffraction Granulometer - Malvern Instrument (SA Parc club de l'universite, France) was used to determine the particle size distribution of the wheat bran. This instrument can detect particle size ranges from 0.06 µ to 3.4 mm. A laser beam is passed through wheat bran to measure the angular variation in intensity of light scattered from the bran (dry channel). The light scattered from larger particle at smaller angle and from smaller particle at larger angle. The particle size was reported as volume equivalent to sphere diameter. A sample of 5 to 10 g was required to carry out the analysis. The results were expressed as D_{10} , D_{50} and D_{90} based on volume distribution of the particles, which represented the size of fine (D_{10}), median (D_{50}) and coarse (D_{90}) bran. From these values, specific surface area and span value of the bran particles were determined. Specific surface area is defined as the total surface area ($4\pi r^2$) per unit volume of a particle.

$$\text{Specific surface area (m}^2\text{/m}^3\text{)} = \frac{12.56(\Sigma r^2)}{v} \quad (2)$$

where r denotes radius of the total volume distribution of the bran fractions and v represents the total volume of the bran. The span value denotes the width of the particle size distribution i.e., distance between two points which are equally spaced from the center of the particle. It was calculated by using the following formula:

$$\text{Span} = \frac{(D_{90}-D_{10})}{D_{50}} \quad (3)$$

2.4 Dough properties

2.4.1 Dough extensibility

The dough extensibility and resistance to extension was measured by using TA.XTplus Texture Analyser-Stable Microsystems with Kieffer dough and gluten extensibility rig (Collar et al., 1999). After mixing, a small amount of non-yeasted dough was made into small strips of 5 cm length by using dough form and clamp. Then, the dough strip was placed over the sample holder and inserted into the rig. The test was performed with a 5 kg load cell, at a pre- test speed of 2 mm/s, test speed of 3.3 mm/s, post-test speed of 10 mm/s with distance of 80 mm, trigger force of 5 g and trigger distance of 2 mm. Once, the trigger force has been attained the hook, it will start to extend the dough until it gets ruptured. Thus, the extensibility of dough (mm) (distance to which the maximum force is experienced by the sample before it ruptures) and resistance to extension (N) (Maximum force required to stretch a sample until it ruptures) were determined by using in-built programme in the exponent software. Ten such measurements were taken for each dough sample.

2.4.2 Dough stickiness

The stickiness of the dough was measured by using TA.XT plus Texture Analyser-Stable Microsystems with the SMS/Chen-Hoseney dough stickiness rig (A/DSC) (Grausgruber et al., 2003). A small amount of dough (1 g) was placed inside the chamber and tightly closed with the lid. Then, the dough was extruded through the small holes in the lid by rotating the internal screw and allowed to rest for 30 seconds. The perspex cap was placed over the sample surface to minimize the moisture loss. Then, the cover was removed and the dough stickiness rig was placed under the 25 mm perspex cylindrical probe attached to the load cell of the texture analyser. Now, the test was performed with a 5 kg load cell, at a pre-test speed of 0.5 mm/s, test speed of 0.5 mm/s, post-test speed of 10 mm/s, applied force of 40 g, contact time of 1 s, return distance of 4 mm and trigger force of 5 g. Finally, the dough stickiness values were recorded in the force-time graph. Three parameters such as dough stickiness (N) (measure of maximum positive force), work of adhesion (g.s) (positive area under the curve) and dough strength or cohesiveness (mm) (distance to which the sample is extended towards the returning probe) were measured using the in-built programme in the exponent software. Ten such measurements were taken for each dough sample.

2.4.3 Dough porosity

The apparent density of the dough was determined by using oil displacement method. Ktenioudaki et al. (2009) proposed a similar method in which dough sample was immersed in xylene using a double cup system. The apparent density measurement setup works on the basis of Archimedes' principle, i.e., oil displacement method. This set up consists of a glass beaker filled with known density of 500 ml of colza oil, a stand to hold the sample inside the oil and a weighing balance. The weight of the dough in air (m_1) and in oil (m_2) (Colza oil; density- 916 kg/m³) was noted down. From these values, the apparent density of the dough was calculated from the following equation:

$$\text{Volume of dough (V}_D\text{)} = V_{D_{gf}} + V_{gas} \quad (4)$$

$$\text{Volume of gas free dough (V}_{D_{gf}}\text{)} = \frac{m_1}{\rho_{D_{gf}}} \quad (5)$$

$$\text{Volume of gas (V}_{gas}\text{)} = \frac{m_2 - V_{D_{gf}} \times \rho_{oil}}{\rho_{oil}} \quad (6)$$

$$\text{Whereas, } m_2 = V_{D_{gf}} \rho_{oil} + V_{gas} \rho_{oil} \quad (7)$$

Where, $\rho_{D_{gf}}$ = density of gas free dough, kg/m³, ρ_{oil} = density of oil, kg/m³, V_{gas} = volume of gas in dough, m³, $V_{D_{gf}}$ = volume of gas free dough, m³, V_D = volume of dough, m³

True density of each ingredients in the recipe was measured by using helium gas pycnometer (AccuPyc 1330 Pycnometer, USA). Then, the density of the degassed dough (kg/m³) was calculated by applying mass, m_i and density of all the ingredients, ρ_i in the following formula:

$$\rho_{D_{gf}} = \sum(m_i \cdot \rho_i) / \sum m_i \quad (8)$$

True density of the dough without bran and with bran was calculated as 1299.9 kg/m³ and 1393.5 kg/m³. Finally, the dough porosity was determined by using the following equation (Sahin et al., 2006).

$$\text{Porosity } \Phi = \frac{V_{gas}}{V_{gas} + V_{D_{gf}}} = 1 - \frac{\rho_{app}}{\rho_{D_{gf}}} \quad (9)$$

Where, ρ_{app} = Apparent density of dough, g/mL, $\rho_{D_{gf}}$ = Gas free dough density, g/mL

2.5 Dough behavior during fermentation

Fermentation time is the time required to tripling the initial volume of the dough. The dough fermentation time and expansion rate was determined where a small amount of dough was placed in a cylindrical flask and a displacement transducer (VRVT050/E/TM, Penny &

Giles, UK) was introduced into the flask which was directly connected with the data logger. Data logger records the change in height of the dough with respect to time during fermentation. The volume expansion of dough was supposed to be equal to CO₂ produced by the yeast during fermentation assuming that no CO₂ gas escaped from the dough (closed dough porosity, and negligible mass exchange with the ambience). From these values, a graph showing the volume of CO₂ produced during fermentation as function of time was obtained. The linear expansion phase of the curve was fitted with a linear trendline and the slope gave the rate of expansion of dough during fermentation in cm³/min.

2.6 Quality characteristics of breads

2.6.1 Specific volume

The baked bread was allowed to cool for an hour. Then, the mass of the bread was noted down and the volume was determined by using volumeter (TexVol BVM-L370LC, France). Bread specific volume (m³/kg) was calculated from the ratio of volume and mass of bread.

2.6.2 Bread crumb porosity

The true density of the bread was determined by using helium gas pycnometer and apparent density was determined by the ratio of bread weight and volume. From these values, the bread crumb porosity was calculated.

2.6.3 Bread crumb pore size distribution

The bread was sliced (Sofraca, France) after storing at 4°C for a period of 24 h. The pore size distribution in the bread crumb was analysed by scanning the bread slices with the flat bed scanner (HP Scanjet G4010-HP, USA). This scanner delivers the scanned image instantaneously. The scanned image was analysed by using imageJ® software (version 1.51j8). Initially, the software was calibrated then the image was duplicated and converted into 8 bit gray scale image. A mask for the image was created for applying threshold. Thresholding is one of the most important step, in which the gray scale image was segmented and converted into binary image. The major advantage of obtaining this binary image is to reduce the complexity of the data and to simplify the process. Auto local threshold method provided in the software was used for image segmentation. Morphological filters such as erosion and dilation, opening and closing were used for structuring the pore area.

Morphological reconstruction is another major part of image processing which was used for constructing an image without altering the original shape of the pores present in the bread slice. Then, particle analysis was performed for analyzing the bread crumb structure. The selected parameters measured in the particle analysis were the pore area and total pore count. The range of pore size and circularity of the pores to be analysed was fixed and the analysed values were exported to Microsoft Office Excel (version 12.0.6612.1000), to generate primary information of the pores. Atlast, image calculator performed arithmetic and logical operations between the original and duplicate images to deliver a final labelled RGB image in the new window. A macro file was created in order to analyse uniformly and to determine the pore area easily throughout the study.

2.8 Statistical analysis

The data was statistically analysed by using one-factor ANOVA with three replication at 5% level of significance with the help of STATGRAPHICS XVI. Fisher's least significant difference (LSD) method was followed to determine significant difference between the bran incorporated recipes.

3 Results and discussion

3.1 Wheat bran particle size distribution

Particle size distribution is the number of particles that can be categorized into various size ranges. The specific surface area and width of the particle was calculated from particle size distribution values (Table 2). The median diameter (D_{50}) of the wheat bran was observed as 750 μm which specifies that 50% of the volume of particles falls greater than the D_{50} value and 50% of the volume of particles falls lesser than the D_{50} value. Noort et al. (2010) quoted that wheat bran particle surface area increased with decrease in particle size i.e., when the median diameter of the wheat bran (D_{50}) was 491.5 μm and 47.9 μm then the specific surface area was noted as 40,626 m^2/m^3 and 590,063 m^2/m^3 . Thus, the increased surface area of bran leads to more interaction between wheat bran and gluten network.

LOCATION TABLE 2

3.2 Dough kneading parameters

Dough kneading parameters such as dough development time, maximum power consumption and specific energy input required during mixing (Table 3) were calculated by using the data recorded during mixing.

The dough developmental time is the optimum mixing time at which maximum energy is required to develop the gluten network. The gluten network started to breakdown upon further mixing. The dough developmental time was found to be 5.4 min for the recipe with 0% bran and 7.1 min for the recipe with 24% bran which indicated that the dough developmental time increased with addition of wheat bran. It was also observed that recipe with 24% wheat bran showed significant ($p < 0.05$) change in dough development time. Similarly, Almeida et al. (2010) and Sanz Penella et al. (2008) stated that the slower water absorption property of wheat bran and dilution of gluten protein, delays the formation of gluten network.

The maximum power consumed during mixing is the maximum power required to develop the gluten network. Further mixing weakened the gluten network which causes linear decrease in the power value. The power consumption depends on the type and amount of bran added in the recipe. Wheat bran disrupts and weakens the gluten structure (Pomeranz et al., 1977). So, less power was required to mix the bran enriched recipe. The power consumption was 322.7 W in the recipe with 0% bran and 281.7 W in the recipe with 24% bran. There was significant ($p < 0.05$) difference between all the recipes except between 16% and 24% wheat bran added recipe. The specific energy input is the energy required to mix per unit mass of the dough. Specific energy input was minimum 419.2 J/kg in the recipe with 24% bran and maximum 554.6 J/kg in the recipe without bran. It was observed that the wheat bran significantly ($p < 0.05$) affected the specific energy input required during mixing.

3.3 Dough porosity

The effect of different proportions of wheat bran on dough porosity was given in the Table 3. Dough porosity depends on the type and quantity of ingredients used in the recipe and on the mixing parameters. The highest porosity value was 25.6% observed in recipe with 24% bran and lowest value was observed as 14.6% in the recipe with 0% bran. It could be explained by understanding that once the amount of wheat bran was increased, the dough mixing time and dough porosity after mixing also increased and the specific energy input was decreased. Campbell et al., (2008a) investigated the effect of wheat bran on dough aeration

and concluded that the wheat bran increased dough aeration during mixing. This causes an increased air entrapment into the dough and hence results in higher dough porosity.

LOCATION TABLE 3

3.4 Dough extensibility and stickiness

Dough extensibility is an important parameter in bread making process. It predetermines the dough raising quality. The values of extensibility (mm) and resistance to extension (N) were measured after mixing. Table 4 indicates that wheat bran decreased dough extensibility and resistance to extension from 64.7 mm to 55.8 mm and 0.32 N to 0.15 N. Thus, the increased concentration of wheat bran in the recipe reduced the dough strength and extensibility property, by interrupting the starch gluten network (Gómez et al. 2011) and minimized the force required to rupture the dough.

Dough stickiness is a combination of adhesion, the interface between dough and surface, and cohesion, the interface within the dough. Therefore, both surface and rheological properties of dough plays major role in stickiness. Dough stickiness should be considered for handling and machinability property of dough. Table 4 shows that addition of wheat bran to the recipe significantly ($p<0.05$) reduced the dough stickiness and adhesiveness.

LOCATION TABLE 4

3.5 Dough behavior during fermentation

The effect of wheat bran on dough behaviour during fermentation was given in the Table 5. It was observed that the bran decreased dough fermentation time to 58.3 min and increased expansion rate of dough during fermentation to 1.5 cm³/min for the recipe with 24% bran. The faster expansion of dough during fermentation was owing to the fact that bran enriched dough produced CO₂ gas more rapidly than the control sample. This might be due to the presence of higher amount of simple sugars, glucose and fructose, as these sugars are consumed earlier by yeast than maltose. (Ralet et al., 1990; MacArthur & D'apponia, 1979).

3.6 Quality characteristics of bread

3.6.1 Specific volume of bread

The bread volume depends on the volume expansion of dough during fermentation and on the baking parameters. The effect of wheat bran on bread specific volume was shown in the Table 5. The maximum specific volume was 3.7 mL/g observed in recipe with 0% bran and minimum volume was 3.3 mL/g observed in recipe with 24% bran. Wheat bran physically disrupted the foam structure of the dough and minimized retention of gas during fermentation. This led to reduction in bread loaf volume (Mosharraf et al., 2009; Polaki et al., 2010 and Majzoobi et al., 2012).

3.6.2 Bread crumb porosity

Bread pores are the air pockets present in the baked bread. Carbon-di-oxide created this interconnected void structure during fermentation process. The degree of porosity plays major role in crumb texture and appearance. The crumb porosity was maximum (79.4%) in recipe with 0% bran and minimum (73.7%) in recipe with 24% bran as shown in Table 5. The bread crumb porosity decreased with an increase in bran content. Similar trend was observed in specific volume of bread. Ognean (2015) stated that crumb porosity was related to specific volume of bread. Analysis of variance showed that different level of wheat bran significantly affected the bread crumb porosity.

LOCATION TABLE 5

3.7 Effect of wheat bran on pore distribution in bread crumb

Scanned 8 bit images of the bread slices with different bran content is shown in Fig. 1a. From these images, it appears clearly that there was differences in the crumb structure. These images were analysed to quantify these differences by calculating the pore surface area distribution in bread crumb. The effect of wheat bran on pore surface area distribution of bread crumb was visualized by plotting mid area of the pores as a function of cumulative frequency of pores present in the surface of bread slice as shown in the Fig. 1b. From the figure, it was observed that in recipe with 0% bran, most of the pores present in the mid area ranging between 0.5 mm^2 - 25.5 mm^2 , whereas in recipe with 24% bran the pores are present in the range of 0.5 mm^2 - 44.5 mm^2 . This vast difference in pore surface area distribution may be due to the effect of wheat bran. The bran alters the actual pore structure of the bread crumb. The pore surface area of the bread crumb depends on the turnover of gas

during mixing, growth of bubbles during proving and homogeneity of crumb porosity (Campbell et al., 2008b). It was observed that the bread crumb median pore area increased with increase in bran content. The focused segment of cumulative frequency of bread crumb pore surface area was shown in the Fig. 1c. Thus, the pore area distribution varied depending on the amount of wheat bran added in the recipe. Katina et al. (2010) studied the effect of wheat bran in bread crumb morphology by 2D image analysis and concluded that crumb evenness and finesse were decreased depending on the addition of different level of bran.

4 Conclusion

From the above work, it was concluded that supplementing different level (w/w) of wheat bran in the recipe significantly ($p < 0.05$) affected the properties of dough and bread. Wheat bran delayed the formation of gluten network. So, the dough developmental time was increased with 24% bran content. At the same time, bran decreased the maximum power consumed and specific energy input required during mixing by weakening the gluten structure. Wheat bran increased dough aeration during mixing and hence resulted in higher dough porosity which was an unexpected result not shown in previous literature.

Wheat bran reduced dough extensibility and resistance to extension. It has been observed that the recipe with 24% bran content decreased dough stickiness and adhesiveness and increased cohesiveness. During fermentation, yeast fed on the fermentable sugars present in the bran and rapidly produced CO_2 gas which resulted in increased expansion rate of dough and reduced fermentation time.

Wheat bran increased the carbon dioxide production in dough during fermentation which caused decrease in specific volume of bread and crumb porosity. The specific volume of bread and crumb porosity decreased by 10.81% and 7.18% respectively as compared with the recipe with 0% bran. Similarly, by image analysis method it was confirmed that wheat bran altered the pore area distribution in the bread crumb.

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518 TABLES and FIGURES

519

520

521 **Table 1**

522 Formulation protocol of sandwich bread.

Ingredients	Ingredient (g/per 100g of flour)			
	Recipe 1 (0% bran)	Recipe 2 (8% bran)	Recipe 3 (16% bran)	Recipe 4 (24% bran)
Flour	100.00	100.00	100.00	100.00
Wheat bran	0.00	8.00	16.00	24.00
Dry yeast	1.33	1.33	1.33	1.33
Sugar	4.99	4.99	4.99	4.99
Salt	1.81	1.81	1.81	1.81
Powder milk	1.50	1.50	1.50	1.50
Purple ibis (improver)	0.49	0.49	0.49	0.49
Soya flour	0.26	0.26	0.26	0.26
Rapeseeds oil	4.01	4.01	4.01	4.01
Water	56.06*	64.39*	72.72*	81.04*
Total	170.44	186.78	203.11	219.43

523 *Amount of water required to hydrate the bran added dough was determined using Δ Hydration coefficient
 524 (calculated as 1.014)

525

526 **Table 2**

527 Wheat bran particle size distribution, specific surface area and span value.

	D ₁₀ (μm)	D ₅₀ (μm)	D ₉₀ (μm)	Specific surface area of particle (m^2/m^3)	Span
Wheat bran	130 \pm 21.65	750 \pm 16.19	1873 \pm 34.72	51,545	2.32

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Table 3

Effect of wheat bran on dough kneading properties and porosity

Wheat bran (%)	Dough development time(min)	Maximum power consumption (W)	Specific energy input (J/kg)	Dough porosity (%)
0	5.4±0.2 ^a	322.7±6.4 ^a	554.6±14.3 ^a	14.6±0.00 ^a
8	5.4±0.1 ^a	303.0±7.9 ^b	480.1±13.1 ^b	18.6±0.01 ^b
16	5.6±0.3 ^a	290.3±2.5 ^c	442.5±18.8 ^c	23.9±0.02 ^c
24	7.1±0.1 ^b	281.7±3.8 ^c	419.2±26.7 ^c	25.6±0.01 ^c

Values are expressed as Mean ± standard deviation followed by same letters are not significantly different (p > 0.05)

Table 4

Effect of wheat bran on dough extensibility and stickiness

Wheat bran (%)	Resistance to extension, force (N)	Extensibility (mm)	Stickiness (N)	Dough strength/ Cohesiveness (mm)	Work of Adhesion (g. s)
0	0.32±0.03 ^a	60.9±8.2 ^a	0.59±0.02 ^a	1.9±0.2 ^a	5.4±0.6 ^a
8	0.22±0.02 ^b	64.7±3.1 ^a	0.50±0.02 ^b	1.9±0.2 ^a	4.8±0.7 ^b
16	0.17±0.02 ^c	62.6±3.1 ^a	0.45±0.02 ^c	2.1±0.2 ^a	4.5±0.5 ^{bc}
24	0.15±0.02 ^c	55.8±5.5 ^b	0.38±0.03 ^d	2.4±0.3 ^b	4.1±0.6 ^c

Values are expressed as Mean ± standard deviation followed by same letters are not significantly different (p > 0.05)

Table 5

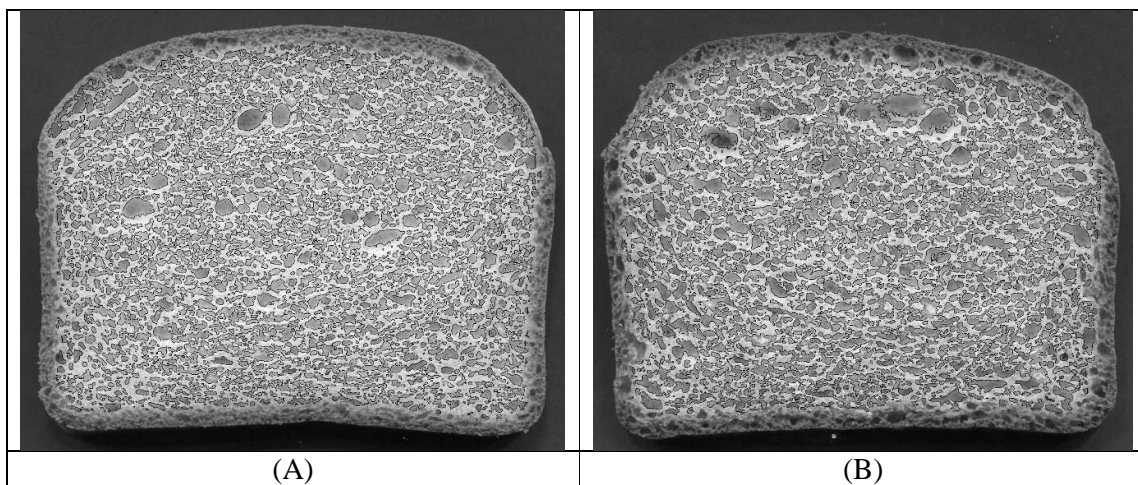
Effect of wheat bran on dough fermentation and bread quality

Wheat bran (%)	Fermentation time (min)	Expansion rate (cm ³ /min)	Bread specific volume (mL/g)	Bread crumb porosity (%)
0	65.9±1.5 ^a	1.4 ±0.03 ^a	3.7±0.12 ^a	79.4±0.003 ^a
8	66.6±0.7 ^a	1.4 ±0.02 ^a	3.5±0.05 ^b	77.9±0.004 ^b
16	62.9±1.3 ^b	1.5 ±0.04 ^{ab}	3.4±0.02 ^b	76.6±0.006 ^c
24	58.3±1.8 ^c	1.5±0.05 ^b	3.3±0.04 ^c	73.7±0.002 ^d

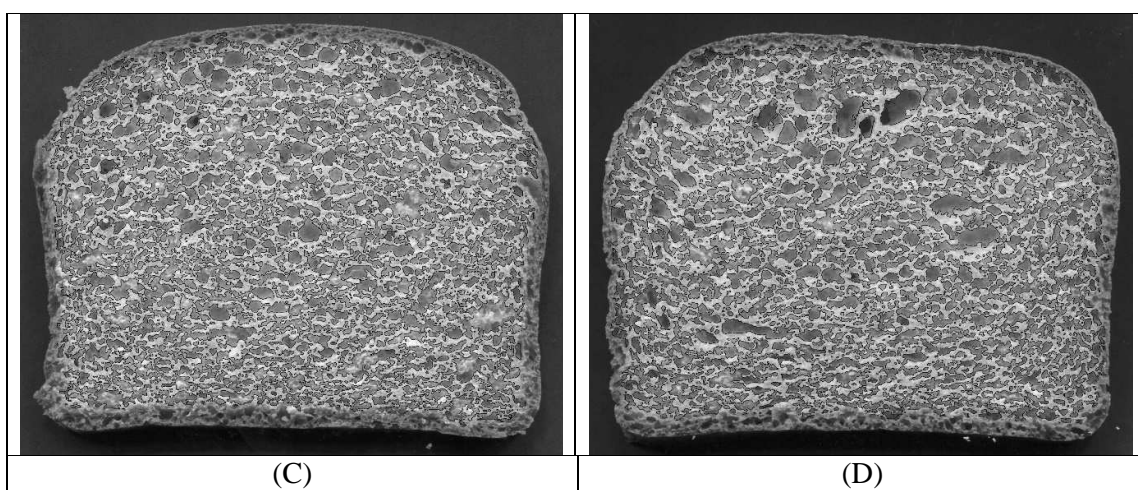
Values are expressed as Mean ± standard deviation followed by same letters are not significantly different (p > 0.05)

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Fig. 1a. Scanned 8 bit image of bread slice.
(A) 0%, (B) 8% (C) 16% and (D) 24% wheat bran

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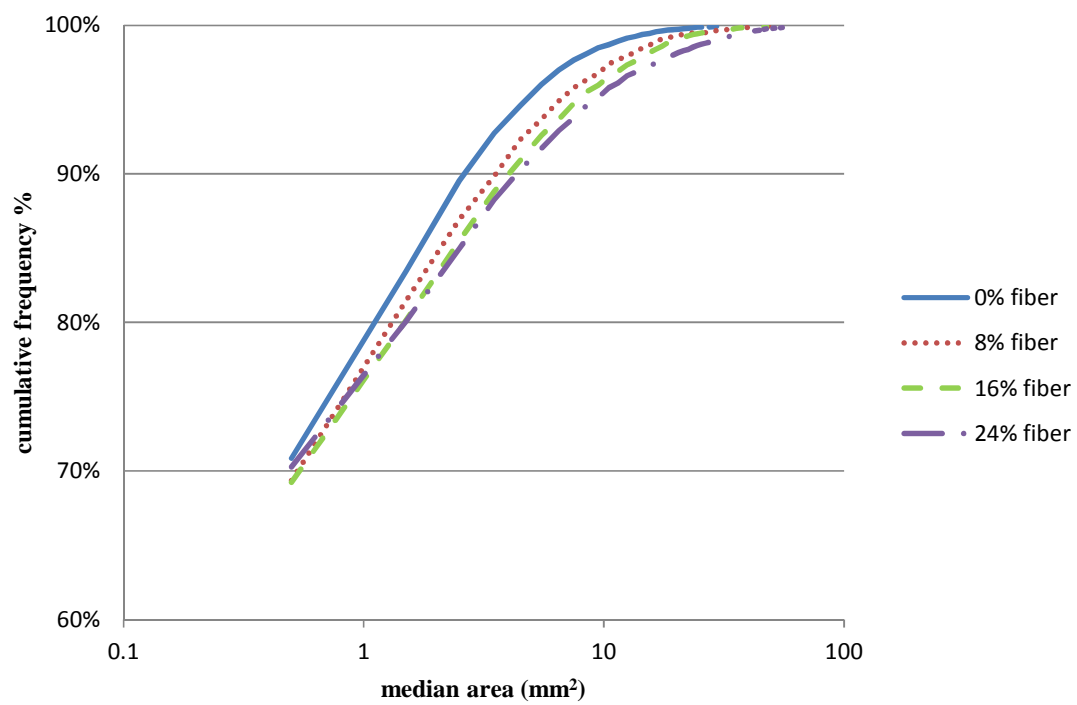


Fig. 1b. Cumulative frequency of bread crumb pore area.

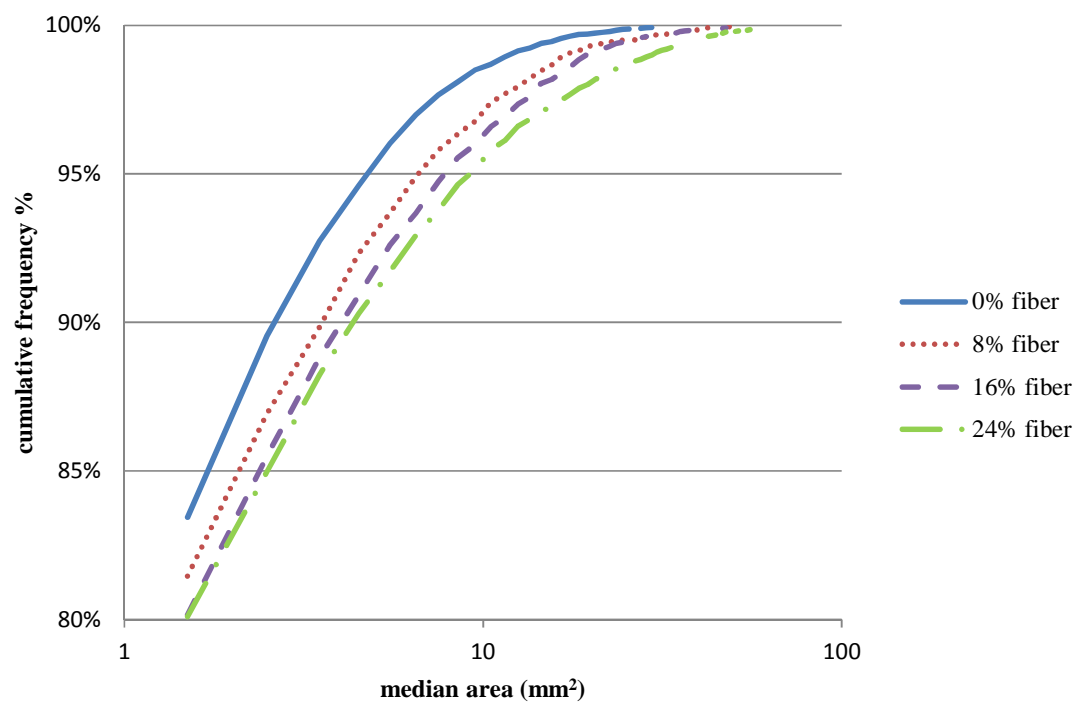


Fig. 1c. Focused segment of cumulative frequency of bread crumb pore area.