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1 **Effect of Supplementation of Wheat Bran on Dough Aeration and Final Bread Volume**

2

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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

74 (1999) evidenced that bread with medium particle sized wheat bran (mean particle size 415
75 μm) had significantly higher specific volume than bread with coarse (609 μm) or fine (278
76 μm) bran.

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

95

96 **2. Materials and Methods**

97 **2.1 Raw materials**

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

105 Generally, most of fibrous materials are hydrophilic in nature. An increased level of
106 pentosans in fiber leads to higher water absorption property (Hoseney, 1984). Rosell et al.
107 (2001) stated that the water binding capacity of fiber enriched dough is higher, because, more
108 number of hydroxyl groups present in the fiber structure permits to hold higher amount of
109 water through hydrogen bonds. Therefore, the water required to hydrate the mixture increased
110 with increase in the level of wheat bran added in the recipe. Thus, the amount of water
111 required to be added in the mixture with respect to wheat bran was determined by using the
112 the following formula.

$$113 \quad \Delta \text{Hydration} = \frac{(\text{Mass of water with bran} - \text{Mass of water without bran})}{(\text{Mass of bran})} \quad (1)$$

114 Where, Δ Hydration= 1.041

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

117 LOCATION OF TABLE 1

118

119 **2.2 Dough preparation and bread making procedure**

120 The water temperature was adjusted in such a way that the cumulative sum of the
121 temperature of flour, ambience and water should be equal to 50°C. Prototype planetary spiral
122 mixer (VMI, Montaigu Vendee, France) was used to knead the dough. There were two
123 different stages carried out during dough mixing: slow speed mixing (50 RPM for the
124 gyratory motion of the spiral hook and 6 RPM for the rotational motion of the mixer's bowl)
125 for 5 min followed by fast speed mixing (120 RPM for the gyratory motion of the spiral hook
126 and 10 RPM for the rotational motion of the mixer's bowl) for 5.35 min. The temperature
127 inside the bowl of the planetary mixer was maintained by cooling water which was supplied
128 by the heat exchanger fixed inside the mixing system. The bowl temperature was fixed as
129 20°C, to maintain uniform dough temperature at the end of mixing. The power required to
130 mix the dough and dough temperature with respect to mixing time were recorded
131 automatically. The dough development time was determined by overmixing the dough. The
132 optimum time required to develop the dough was found by plotting the graph between dough
133 mixing time and maximum power consumed by mixer during mixing. The optimum mixing
134 time of the dough varied with amount of bran added to the recipe. After mixing, bulk of the

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

143

144 2.3 Wheat bran particle size analysis

145 A Laser Diffraction Granulometer - Malvern Instrument (SA Parc club de l'universite,
146 France) was used to determine the particle size distribution of the wheat bran. This
147 instrument can detect particle size ranges from 0.06 μ to 3.4 mm. A laser beam is passed
148 through wheat bran to measure the angular variation in intensity of light scattered from the
149 bran (dry channel). The light scattered from larger particle at smaller angle and from smaller
150 particle at larger angle. The particle size was reported as volume equivalent to sphere
151 diameter. A sample of 5 to 10 g was required to carry out the analysis. The results were
152 expressed as D₁₀, D₅₀ and D₉₀ based on volume distribution of the particles, which
153 represented the size of fine (D₁₀), median (D₅₀) and coarse (D₉₀) bran. From these values,
154 specific surface area and span value of the bran particles were determined. Specific surface
155 area is defined as the total surface area (4πr²) per unit volume of a particle.

$$156 \quad \text{Specific surface area (m}^2\text{/m}^3\text{)} = \frac{12.56(\Sigma r^2)}{v} \quad (2)$$

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

$$161 \quad \text{Span} = \frac{(D_{90}-D_{10})}{D_{50}} \quad (3)$$

162 2.4 Dough properties

163 **2.4.1 Dough extensibility**

164 The dough extensibility and resistance to extension was measured by using
165 TA.XTplus Texture Analyser-Stable Microsystems with Kieffer dough and gluten
166 extensibility rig (Collar et al., 1999). After mixing, a small amount of non-yeasted dough was
167 made into small strips of 5 cm length by using dough form and clamp. Then, the dough strip
168 was placed over the sample holder and inserted into the rig. The test was performed with a
169 5 kg load cell, at a pre- test speed of 2 mm/s, test speed of 3.3 mm/s, post-test speed of
170 10 mm/s with distance of 80 mm, trigger force of 5 g and trigger distance of 2 mm. Once, the
171 trigger force has been attained the hook, it will start to extend the dough until it gets ruptured.
172 Thus, the extensibility of dough (mm) (distance to which the maximum force is experienced
173 by the sample before it ruptures) and resistance to extension (N) (Maximum force required to
174 stretch a sample until it ruptures) were determined by using in-built programme in the
175 exponent software. Ten such measurements were taken for each dough sample.

176 **2.4.2 Dough stickiness**

177 The stickiness of the dough was measured by using TA.XT plus Texture Analyser-
178 Stable Microsystems with the SMS/Chen-Hoseney dough stickiness rig (A/DSC)
179 (Grausgruber et al., 2003). A small amount of dough (1 g) was placed inside the chamber and
180 tightly closed with the lid. Then, the dough was extruded through the small holes in the lid by
181 rotating the internal screw and allowed to rest for 30 seconds. The perspex cap was placed
182 over the sample surface to minimize the moisture loss. Then, the cover was removed and the
183 dough stickiness rig was placed under the 25 mm perspex cylindrical probe attached to the
184 load cell of the texture analyser. Now, the test was performed with a 5 kg load cell, at a pre-
185 test speed of 0.5 mm/s, test speed of 0.5 mm/s, post-test speed of 10 mm/s, applied force of
186 40 g, contact time of 1 s, return distance of 4 mm and trigger force of 5 g. Finally, the dough
187 stickiness values were recorded in the force-time graph. Three parameters such as dough
188 stickiness (N) (measure of maximum positive force), work of adhesion (g.s) (positive area
189 under the curve) and dough strength or cohesiveness (mm) (distance to which the sample is
190 extended towards the returning probe) were measured using the in-built programme in the
191 exponent software. Ten such measurements were taken for each dough sample.

192 **2.4.3 Dough porosity**

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

$$201 \quad \text{Volume of dough (V}_D) \quad = \quad V_{D_{gf}} + V_{gas} \quad (4)$$

$$202 \quad \text{Volume of gas free dough (V}_{D_{gf}}) \quad = \quad \frac{m_1}{\rho_{D_{gf}}} \quad (5)$$

$$203 \quad \text{Volume of gas (V}_{gas}) \quad = \quad \frac{m_2 - V_{D_{gf}} \times \rho_{oil}}{\rho_{oil}} \quad (6)$$

$$204 \quad \text{Whereas, } m_2 \quad = \quad V_{D_{gf}} \rho_{oil} + V_{gas} \rho_{oil} \quad (7)$$

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

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

$$211 \quad \rho_{D_{gf}} = \frac{\sum(m_i * \rho_i)}{\sum m_i} \quad (8)$$

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

$$215 \quad \text{Porosity } \Phi = \frac{V_{gas}}{V_{gas} + V_{D_{gf}}} = 1 - \frac{\rho_{app}}{\rho_{D_{gf}}} \quad (9)$$

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

217 2.5 Dough behavior during fermentation

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

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

229 **2.6 Quality characteristics of breads**

230 **2.6.1 Specific volume**

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

235 **2.6.2 Bread crumb porosity**

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

239 **2.6.3 Bread crumb pore size distribution**

240 The bread was sliced (Sofraca, France) after storing at 4°C for a period of 24 h. The
241 pore size distribution in the bread crumb was analysed by scanning the bread slices with the
242 flat bed scanner (HP Scanjet G4010-HP, USA). This scanner delivers the scanned image
243 instantaneously. The scanned image was analysed by using imageJ® software (version
244 1.51j8). Initially, the software was calibrated then the image was duplicated and converted
245 into 8 bit gray scale image. A mask for the image was created for applying threshold.
246 Thresholding is one of the most important step, in which the gray scale image was segmented
247 and converted into binary image. The major advantage of obtaining this binary image is to
248 reduce the complexity of the data and to simplify the process. Auto local threshold method
249 provided in the software was used for image segmentation. Morphological filters such as
250 erosion and dilation, opening and closing were used for structuring the pore area.

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

261 **2.8 Statistical analysis**

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

266 **3 Results and discussion**

267 **3.1 Wheat bran particle size distribution**

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

277 LOCATION TABLE 2

278 **3.2 Dough kneading parameters**

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

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

291 The maximum power consumed during mixing is the maximum power required to
292 develop the gluten network. Further mixing weakened the gluten network which causes linear
293 decrease in the power value. The power consumption depends on the type and amount of bran
294 added in the recipe. Wheat bran disrupts and weakens the gluten structure (Pomeranz et al.,
295 1977). So, less power was required to mix the bran enriched recipe. The power consumption
296 was 322.7 W in the recipe with 0% bran and 281.7 W in the recipe with 24% bran. There was
297 significant ($p < 0.05$) difference between all the recipes except between 16% and 24% wheat
298 bran added recipe. The specific energy input is the energy required to mix per unit mass of
299 the dough. Specific energy input was minimum 419.2 J/kg in the recipe with 24% bran and
300 maximum 554.6 J/kg in the recipe without bran. It was observed that the wheat bran
301 significantly ($p < 0.05$) affected the specific energy input required during mixing.

302 **3.3 Dough porosity**

303 The effect of different proportions of wheat bran on dough porosity was given in the
304 Table 3. Dough porosity depends on the type and quantity of ingredients used in the recipe
305 and on the mixing parameters. The highest porosity value was 25.6% observed in recipe with
306 24% bran and lowest value was observed as 14.6% in the recipe with 0% bran. It could be
307 explained by understanding that once the amount of wheat bran was increased, the dough
308 mixing time and dough porosity after mixing also increased and the specific energy input was
309 decreased. Campbell et al., (2008a) investigated the effect of wheat bran on dough aeration

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

312 LOCATION TABLE 3

313 **3.4 Dough extensibility and stickiness**

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

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

326

327 LOCATION TABLE 4

328

329 **3.5 Dough behavior during fermentation**

330 The effect of wheat bran on dough behaviour during fermentation was given in the
331 Table 5. It was observed that the bran decreased dough fermentation time to 58.3 min and
332 increased expansion rate of dough during fermentation to $1.5 \text{ cm}^3/\text{min}$ for the recipe with
333 24% bran. The faster expansion of dough during fermentation was owing to the fact that bran
334 enriched dough produced CO_2 gas more rapidly than the control sample. This might be due to
335 the presence of higher amount of simple sugars, glucose and fructose, as these sugars are
336 consumed earlier by yeast than maltose. (Ralet et al., 1990; MacArthur & D'apponia,
337 1979).

338 **3.6 Quality characteristics of bread**

339 **3.6.1 Specific volume of bread**

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

347 **3.6.2 Bread crumb porosity**

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

356

357 LOCATION TABLE 5

358

359 **3.7 Effect of wheat bran on pore distribution in bread crumb**

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

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

378

379 **4 Conclusion**

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

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

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

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516

517

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

528

529

530 **Table 3**

531 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

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

534 **Table 4**

535 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

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

538 **Table 5**

539 Effect of wheat bran on dough fermentation and bread quality

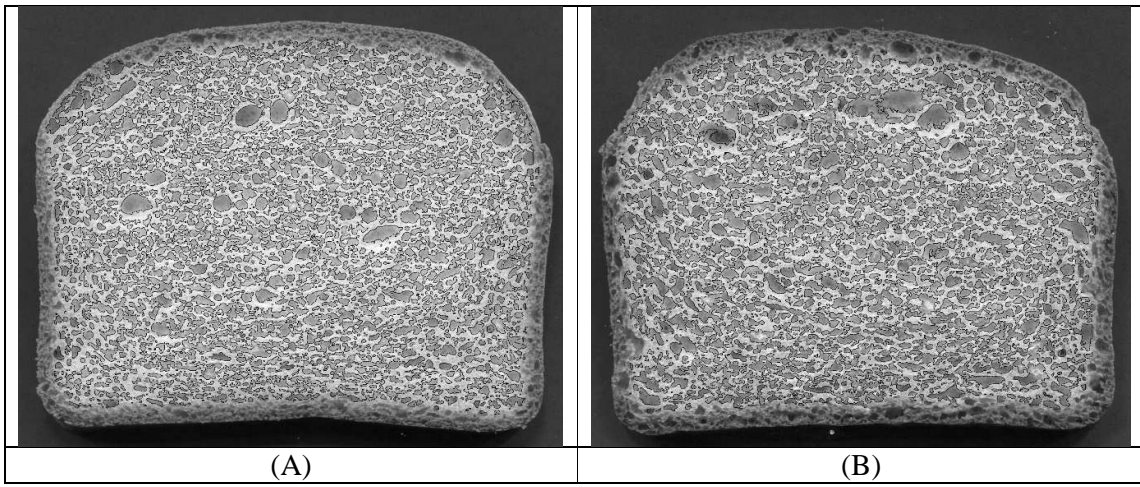
Wheat bran (%)	Fermentation time (min)	Expansion rate (cm ³ /min)	Bread specific volume (mL/g)	Bread crumb porosity (%)
0	65.9±1.5 ^a	1.4 ±0.03 ^a	3.7±0.12 ^a	79.4±0.003 ^a
8	66.6±0.7 ^a	1.4 ±0.02 ^a	3.5±0.05 ^b	77.9±0.004 ^b
16	62.9±1.3 ^b	1.5 ±0.04 ^{ab}	3.4±0.02 ^b	76.6±0.006 ^c
24	58.3±1.8 ^c	1.5±0.05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

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

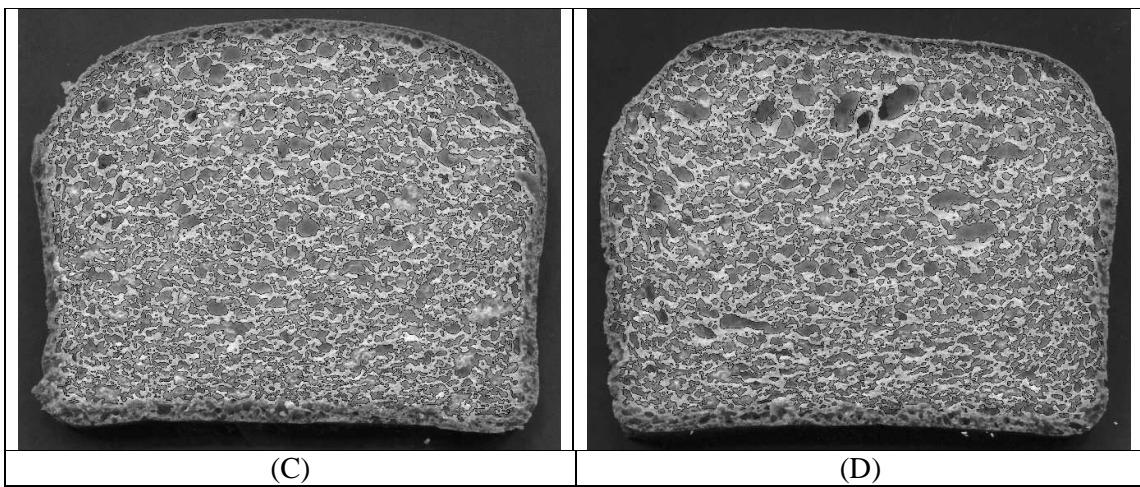
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Fig. 1a. Scanned 8 bit image of bread slice.
(A) 0%, (B) 8% (C) 16% and (D) 24% wheat bran

547

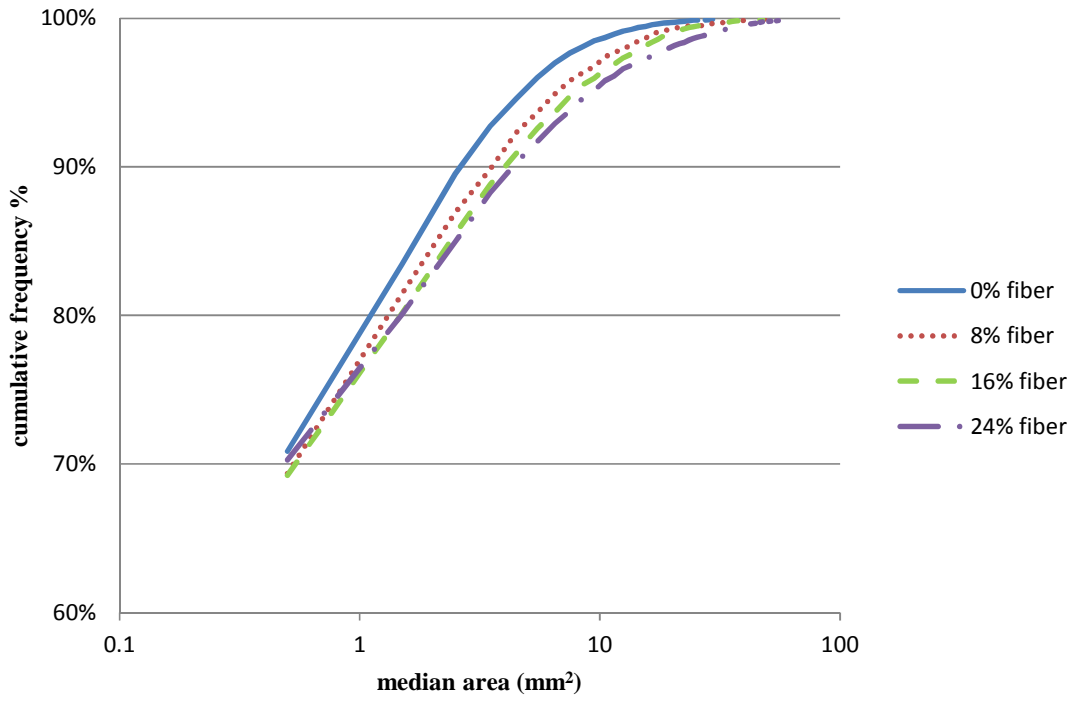
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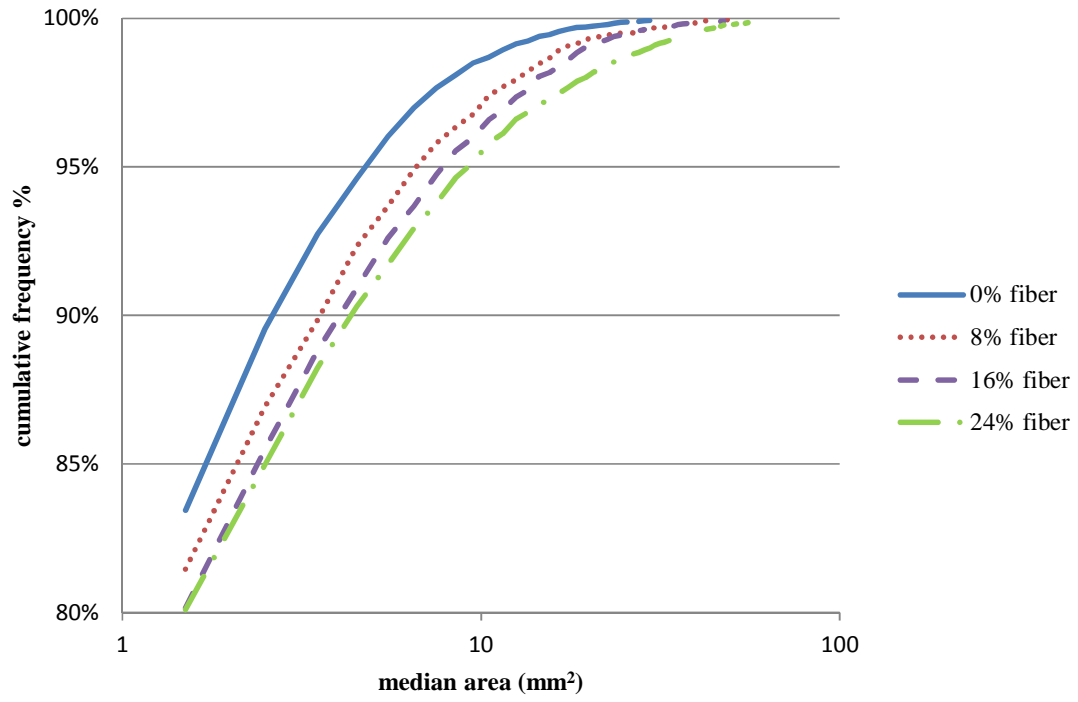
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Fig. 1b. Cumulative frequency of bread crumb pore area.

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560

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

562