EVALUATION OF THE FUNCTIONAL, RHEOLOGICAL AND SENSORY PROPERTIES OF HIGH-FIBER BREAD CONTAINING WHEAT AND LEGUME BRANS

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Abstract

We evaluated the quality of conventional bread made with whole wheat flour (WWF) and high-fiber leguminous bran from wheat, faba beans, chick peas, pigeon peas and soya beans. The functional, rheological and organoleptic qualities of the composite flours and the bread baked from them were investigated. The water retention capacity of the composite flours was increased significantly by adding legume brans for all blends except the wheat/faba bean bran composite flour. The bulk density of whole wheat flour was also significantly reduced by adding wheat and legume brans, affecting the rheology of the dough. Increasing the level of bran in WWF increased its water absorption and dough development time and decreased dough stability compared with WWF, except for high-bran wheat flour. Sensory evaluation showed that palatable bread can be produced from wheat flour fortified with chick pea, soya bean or faba bean brans.

Key words: Wheat bran, legume bran, high-fiber bread, functional properties, rheological properties organoleptic quality.

INTRODUCTION

Consumers are becoming increasingly aware of the need to eat healthy, high-quality foods containing ingredients which provide additional health benefits beyond basic nutritional requirements (Ndife et al., 2009). Bread fortification can play a major dietetic role in solving certain nutritional disorders and improving the health of the population. Diets rich in fiber from cereals, nuts, fruits and vegetables have a good effect on health; their consumption has been related to decreased incidence of several diseases (Dhingra et al., 2012). In 2001, the American Association of Cereal Chemists defined dietary fiber as the “edible part of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine” (American Association of Cereal Chemists, 2016).
The current recommendation for the daily intake of fiber is 25 g. However, the average daily intake of fiber in the United States is only 10–15 g (Gelroth et al., 200). Nowadays, the decortication of cereals is reducing fiber intake in countries, such as Sudan, where whole grain flours are being replaced by refined grain flours. Fiber is commonly added to foods to increase their fiber content to promote health and improve various functional properties such as water and oil retention, viscosity, texture and mouthfeel. The most well-known and widely consumed fiber-enriched foods on the retail market are breakfast cereals and bakery products such as whole grain breads (Gomez et al., 2003), yoghurt (STAFFOLO ET AL., 2004), as well as meat products (Vema et al., 2010) and drinks (Hasim et al., 2009). Nevertheless, white bread is still widely consumed. Therefore, developing breads with a higher dietary fiber content is considered the best way to increase fiber intake to the required level (Wang et al., 2002). For this purpose, bran is an excellent source of dietary fiber. Bread can be enriched with dietary fiber: wheat bran (Sidhu et al., 1999), gums (Pomeranz et al., 1977) and α-glucans (KNUCKLES ET AL., 1997). The literature also reports the potential use of defatted rice bran as a source of dietary fiber for incorporating into bread (Abdul-Hamid and Luan, 2000). However, adding these fibers often causes a negative effect on the quality of the final bread. Adding too much fiber produces bread of poor quality in terms of its texture, loaf volume and appearance (Gomez et al., 2003; Wang et al., 2002). It has been suggested that these negative effects on the dough structure and loaf volume are caused by the dilution of the gluten network, which favors gas retention rather than gas production (Dewettinck et al., 2008; Fiman et al., 2008; Elleuch et al., 2011). Replacing a portion of wheat flour with legume fiber in bread-making has typically used ground legume hulls (Wang et al., 2002; Dalgetty and Baik, 2006; Sievert et al., 1990). Fortifying bread with pea hulls decreased loaf volume, increased water absorption and decreased overall bread quality as the substitution level increased (Sosulski and Wu, 1988). The fiber source and the quantity used can produce different effects on process parameters and the final quality characteristics of the bread (Almeida et al., 2003). Fibers from legumes in bread-making have received much less attention compared with fibers from cereals. Therefore, the aim of the present study is to determine and compare the functional properties of wheat and legume fibers when added as bran to conventional bread. The study also aims to determine the influence of the different fibers on the rheological properties of bread dough and the final quality and organoleptic quality of the resulting breads.

MATERIALS AND METHODS

Materials. Wheat bran was obtained from the Food Research Centre (Shambat, Sudan). Faba bean (Vicia faba), chick pea (Cicer arietinum), pigeon pea (Cajanus cajan), wheat flour, salt and dry yeast were obtained from the local market. Soya bean (Glycine max) was obtained from the Arab Corporation for Investment and Agricultural Development (Khartoum, Sudan). Chemicals of analytical grade were obtained from the Food Research Centre (Faculty of Agriculture, University of Khartoum, Sudan).

Methods of preparation

Wheat and Legume Brans: Legume seeds were cleaned by aspiration, sieving and manual separation of impurities by hand. To obtain high-fiber bran, the legume seeds were first decorticated. The wheat and legume brans were milled at one degree using Junior mill (model falling number A.BN 71849, Brabender, Duisburg Germany) Finally, the mixture was sieved using a 355-mesh screen, mixed well then stored until further analysis and use.

Wheat Flour: Whole wheat flour was used as a base for making conventional bread with bran extracted from wheat and from the different legumes.

Composite Flour by adding Bran to Wheat Flour: To prepare composite flour containing 4% fiber content, the Pearson square was used to calculate the amount of fiber in the form of bran from various sources needed to be added to the wheat flour.

Bread Samples: The various blends of bran/wheat flour were made into bread according to a previous study (Badi et al., 1978), using the following formula: flour, 250 g; dry yeast, 2.5 g; salt, 2.5 g; ascorbic acid at 80 ppm; and water according to the type of bread.

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In addition, the effect of adding a flour improver (Megamix) to all the high fiber breads was compared with its omission. All ingredients were weighed and made into dough using a mixer (Model 800, Spar Food Machinery Mfg. Co. Ltd., Ta-Li City, Taiwan) for 5 min at medium speed. The dough was allowed to rest for 15 min at room temperature (38 ± 2 °C), then weighed into three portions of 120 g each. The three dough portions were roughly molded into balls and allowed to rest for another 15 min. The dough was then molded again, placed into pans and placed in the fermentation cabinet for the final proof (45 min). Finally, the fermented dough samples were baked into bread in a Simon Rotary Test Oven (Henry Simon Ltd, Stockport, UK) at 220-250 °C for 20-25 min using saturated steam.

The loaves were cooled and then sliced using an electric knife. Some slices were dried in single layers on trays at room temperature (38 ± 2 °C) for 48 h, ground into powder, placed in glass jars, and then stored at room temperature until further use.

Analysis of Functional Properties of Flours: Water Retention Capacity. The water retention capacity (WRC) of the flour samples was measured using the method of Lin et al (1974) with modifications (Quinn and Beuchat, 1975). A 10% suspension (3 g of sample/30 ml distilled water) was stirred in a 50 ml centrifuge tube for 2 min. After 30 min, the tube was centrifuged for 20 min at a speed of 4400 revolutions per min. The freed water was carefully decanted into a graduated cylinder and the volume was recorded. The WRC was expressed as ml water retained by 100 g flour.

Fat Absorption Capacity: The fat absorption capacity (FAC) of the flours was measured by a modified method (Lin et al., 1974). Four g of flour was added to 20 ml of cotton seed oil in a 50-ml centrifuge tube. The suspension was stirred for 5 min. After 25 min, the suspension was centrifuged at 4400 rpm for 20 min at room temperature. The freed fat was measured and the FAC was expressed as ml of fat bound by 100 g flour.

Bulk Density. The bulk density (BD) was determined by a previous method (Wang and Kinsella, 1976). Ten g flour was placed in a 25 ml graduated cylinder and compacted by gently tapping the cylinder on the bench ten times. The volume of the sample was recorded. The BD was expressed as g per ml.

Analysis of Rheological Properties using a Farinograph: The rheological properties of the dough prepared from wheat flour and the flour blends were measured using the Farinograph (Brabender) according to the AACC method (American Association of Cereal Chemists, 1983). The flour sample (50 g, 14% moisture content) was placed in a clean dry Farinograph mixing bowl at 30 °C. The farinographic parameters obtained from the farinogram were water absorption, dough development time, dough stability and dough weakening.

Organoleptic Evaluation: The bread samples were assessed organoleptically using the ranking test (Ihekoronye and Ngoddy, 1985). Fifteen panelists were served coded bread samples in dishes and asked to examine the samples and rank them for color, odor, taste, aftertaste, texture and overall preference using 1 as the best and 5 as the worst for each quality attribute and overall preference.

Statistical Analysis: The data from replicates of each sample were analyzed using SAS (SAS Institute, Cary, NC, USA). An analysis of variance was performed to determine any significant effects in all parameters measured by using complete randomized design. Duncan’s multiple range test was used to determine the significance of differences between mean values from all data collected. The sums of ranks from the organoleptic evaluation were analyzed statistically at the 5% level of significance using the non-parametric Kruskal–Wallis test. This tested the significance of any differences between the types of bread.

RESULTS AND DISCUSSION

Functional Properties of Wheat/legume Bran Composite Flours: Table 1 summarizes the functional properties of the wheat/legume bran composite flours. Adding wheat and legume brans to WWF significantly ($p \leq 0.05$) increased the water retention capacity (WRC) of wheat flour from 83.0 to
132.2 ml/100g in all blends except for W/FBB/CF, whereas the low level of added faba bean bran did not affect the WRC of the WWF. A similar increase in water absorption has been observed in dough fortified with pea bran (Susulski and Wu, 1988). The results of Susulaki and Wu (1988) confirmed our findings. The difference in water uptake by the composite flour may be attributable to differences in the particle size of the bran added (Gordon, 1989). Higher water absorption has been observed in dough prepared from whole wheat flour with fine bran than with coarse bran (Cai et al., 2014) and fiber from legume hulls provided greater water absorption than fiber extracted from cereals (Lo, 1989). It has also been demonstrated that water retention in the insoluble fiber fractions of chickpeas, peas and lentils was much higher than that in the respective hull fractions (Dalgetty and Baik, 2006). Pea fiber formulations have been shown to be better suited for enriching cookies than other fiber sources (orange or oat), and have been used as a functional ingredient at levels up to 30% (Piteira et al., 2006). The WRC of bran was significantly related to the loaf volume of whole wheat flour bread (Cai et al., 2014).

The fat absorption capacity (FAC) of WWF (Table 1), 99.5 ml/100 g, was increased by the incorporation of wheat, pigeon pea and soya bean bran. Adding faba bean and chick pea bran to WWF lowered the FAC of the two blends to less than the control. This may be caused by the different functional properties and characteristics of the different types of bran. The FAC of flour blends has been found to be related to their density (Gordon, 1989). The ability of dietary fibers to retain oil can be important in food applications. For example, retaining oil is important for avoiding fat losses upon cooking (Anderson and Bery, 2001a&b) and for nutrition, because the ability to absorb or bind bile acids and increase their excretion is associated with the reduction of plasma cholesterol (Tosh and Yada, 2010).

The bulk density (BD) of WWF was found to be 0.66 g/ml (Table 1) and that of the composite flours ranged from 0.52 to 0.65 g/ml. The BD of WWF was significantly \((p \leq 0.05)\) reduced by adding wheat and legume brans. Increasing the level of bran in WWF significantly \((p \leq 0.05)\) decreased the BD of the blend. This indicates that more volume is needed to make use of high-fiber bran composite flour compared with wheat flour.

**Rheological Properties of Dough Prepared from Cereal/legume Brans Composite Flours.** Table 2 summarizes the farinogram values of dough prepared from wheat/legume bran composite flours. The water absorption of wheat flour was affected by incorporating legume bran. For example, the water absorption of whole wheat flour increased from 63.4 to 73.2% with soya bean bran (W/SBB/CF). Although the water absorption of wheat flour is directly associated with its gluten level and quality (Tsen et al., 1975), it may increase because of the strong water-binding ability of fibers. This increase in water absorption has also been reported using different sources of fibers, such as wheat bran (Pomeranz et al., 1976; Posner, 1991), wheat fiber (Gomez et al., 2003), locust bean gum (Wang et al., 2002), cellulose (Gomez et al., 2003; Pomeranz et al., 1977), rice bran (Sharma and Chauhan, 2002), alginate, hydroxyl propyl methyl cellulose, k-carrageenan and xanthan (Rosell et al., 2001), and wheat, maize starch and locust bean gum (Almeida et al., 210). Because of the high water-holding capacity of most fibers, the amount of water generally needs to be increased when using higher levels of fiber in doughs (Gelroth and Ranhotra, 2001). The dough development time (min) of the WWF was 5.0 min (Table 2). Adding bran to WWF increased the dough development time from 5.0 to 10.7 min for WF/HB. The dough development time of wheat flour has also been found to increase by fortifying with soy and legume bran (Tsen et al., 1975), wheat bran, resistant starch, locust bean gum (Almeida et al., 210), and wheat and other fibers (Gomez et al., 2003). It can thus be concluded that mixing wheat flour and legume bran results in dough that requires a longer mixing time. The increase in the dough development time was directly related to increased levels of bran in the wheat flour.

The dough stability values (min) of WWF and the composite flours are shown in Table 2. There were obvious reductions in the stability of the different doughs prepared from wheat flour blended with legume brans (7.3-12.0 min) compared with the control (WWF) (14.5 min), but there was an increase in dough stability for WF/HB (15.1 min). These results
agreed with previous work stating that farinogram stability in WWF decreased if diluted with non-wheat flour (D’Appolonia, 1971) and that adding different sources of fiber to wheat flour decreased dough stability (Gomez et al., 2003). While wheat flour alone provided a stability value of 12.25 min, the wheat flour and fiber composite flours exhibited lower values (4.75-8.75 min) (Almeida et al., 2010). This finding can be summarized as: the greater the dough stability, the stronger the flour. This shows that fibers weaken the dough. However, fibers give consistency but dilute the gluten that is responsible for giving the dough strength and tolerance to mixing (Almeida et al., 2010).

**Organoleptic Quality of High-Fiber Bread.** Tables 3 and 4 show the results from the sensory evaluation of bread containing high fiber from wheat and different sources of legume bran either with or without the flour improver. The color of the high-fiber bread was dark with a brownish appearance. The darker colors of whole wheat bread and fortified bread and biscuits have been widely reported (Singh et al., 2000; Akhtar et al., 2008; Serrem et al., 2011). Dark colors of bread have been shown to be related to an increase in fiber content (Hu et al., 2007).

A hard crumb texture, caused by an increased level of wheat bran substitution, has been reported (Eiman et al., 2008). The baking conditions (oven temperature and time variables), the bread components such as fibers, starch and gluten if damaged or not and the amounts of water absorbed during mixing all contribute to the final texture of the bread (Akhtar et al., 2008; Serrem et al., 2011; Bakke and Vickers, 2007).

Most panelists disliked the bean flavor of the legume bran used in high-fiber bread, especially in bread with high fiber levels. This flavor is commonly associated with legumes (Okoye and Okaka, 2009). The baking properties of composite flours are often weak and with poor organoleptic attributes of the baked product, because the gluten has been diluted (Dewettinck et al., 2008; Jideani and Onwubali, 2009).

The overall sensory evaluation reflected that the samples of bread containing wheat or pigeon pea bran were less acceptable and less preferred than the other types of enriched bread. It was clear that panelists preferred the breads containing chick pea, soya bean and faba bean fibers.

Adding a flour improver such as Megamix clearly improved the quality of bread containing faba bean bran (FBBD) (Table 4). Palatable bread could be produced from wheat flour fortified with chickpea, soy bean or faba bean brans (CPBD, SBBD and FBBD). Accordingly, these three types of bread were selected for assessment.

The bean flavor and bitter aftertaste of legumes limits the use of legume bran and flours, with these disadvantages being reflected in the properties and preferences of baked products. This may suggest that modifying the seed before use by roasting or germination could improve such attributes. Roasted legume flour can provide a more appealing bread aroma and greater loaf volume than the cooked version, thus roasting might be the most appropriate preprocessing method for incorporating legume flours into bread (Baik and Han, 2012).

Considering the nutritional physiological implications of adding dietary fiber to foods, the key factors are color, taste, odor, cost and availability (Gordon, 1989), as well as the source of fiber, fiber content and composition of macronutrients. The type and quantity of the fiber source used produce different effects on process parameters and the final quality characteristics of the bread (Almeida et al., 2003).

High-fiber bread containing legume bran can be a source of protein, fiber and minerals; thus, it has multi-physiological functions (Johnson et al., 1985). Total carbohydrate content was observed to have decreased by including wheat and legume brans. Increasing the level of bran in WWF decreased its available carbohydrates content. Thus, fiber-enriched bread has been successful as a low calorie food for improving the dietary control of diabetes (Anderson et al., 1987). Dough functionality can be improved by optimizing the combination of fibers when formulating fiber-enriched dough (Collar et al., 2007). An ideal fiber ingredient, if it existed, would probably be a blend of fibers from different sources. Additives are generally improving the overall quality of fibre-enriched bread but, in general, differences with white bread still remain.
In conclusion, dietary fiber has been shown to have important health implications in reducing the risk of chronic diseases. Conventional wheat-based bread was enriched with bran from wheat and different legumes such as faba bean, chick pea, pigeon pea and soya bean. The functionality of the composite flours showed a significant ($p \leq 0.05$) increase in water retention capacity for all the blends except the wheat/faba bean bran composite flour. The bulk density of wheat flour was significantly ($p \leq 0.05$) reduced by adding bran to the whole-wheat flour. Finally, the quality of the high-fiber bread was noticeably reduced when a higher level of bran was added to the whole-wheat flour. The improver caused a significant ($p \leq 0.05$) increase in loaf volume in wheat and faba bean high-fiber breads. The overall sensory evaluation showed that acceptable bread can be produced from wheat flour fortified with either chickpea, soy bean or faba bean bran. Further research should focus on how to improve the organoleptic qualities and hence the palatability of fiber-enriched bread.

| Table 1. Functional Properties of Wheat/legume Bran Composite Flours* |
|-----------------------------|-----------------|-----------------|-----------------|
| sample                     | WRC (ml/100g)   | FAC (ml/100g)   | BD (g/ml)       |
| WWF                        | 83.0c           | 99.5c           | 0.66a           |
| WF/HB                      | 132.2a          | 149.2a          | 0.52f           |
| W/FBB/CF                   | 83.2c           | 89.2d           | 0.65b           |
| W/PPB/CF                   | 98.9c           | 101.7c          | 0.61d           |
| W/SBB/CF                   | 115.8b          | 111.7b          | 0.59e           |

* Mean values with different superscript letters in each column differ significantly ($p \leq 0.05$).

| Table 2. Farinogram readings of dough prepared from wheat/legume bran composite flours. |
|-------------------------------|-----------------|-----------------|-----------------|
| sample                       | Water absorption (%) | Dough Development time (min) | Dough stability (min) | Dough weakening (BU) |
| WWF                           | 63.4             | 5.0             | 14.5            | 48.0              |
| WF/HB                         | 71.8             | 10.7            | 15.1            | 12.0              |
| W/FBB/CF                     | 68.5             | 7.0             | 7.3             | 70.0              |
| W/PPB/CF                     | 68.4             | 6.7             | 9.2             | 47.0              |
| W/SBB/CF                     | 73.2             | 9.7             | 12.0            | 15.0              |

* Mean values with different superscript letters in each column differ significantly ($p \leq 0.05$).

| Table 3. Organoleptic quality of high-fiber bread containing no improver Sum of ranks * |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bread Source                  | Color           | Odor            | Taste           | Aftertaste      | Texture         | Preference      |
| WBD                           | 61a             | 51a             | 53a             | 56a             | 70a             | 57a            |
| FBBD                          | 49b             | 44a             | 42a             | 36a             | 40b             | 45a            |
| CPBD                          | 22c             | 32a             | 34a             | 33a             | 26c             | 27b            |
| PPBD                          | 66a             | 67b             | 67b             | 66b             | 62b             | 71c            |
| SBBD                          | 27c             | 30c             | 30c             | 34a             | 26c             | 25b            |

* Any two sums of ranks having different subscript letter(s) differ significantly ($p \leq 0.05$).

| Table 4. Organoleptic quality of high-fiber bread containing improver Sum of ranks * |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Bread Source                  | Color           | Odor            | Taste           | Aftertaste      | Texture         | Preference      |
| WBD                           | 65a             | 33a             | 55a             | 57a             | 64a             | 64a            |
| FBBD                          | 40b             | 46a             | 36a             | 37a             | 48b             | 40b            |
| CPBD                          | 15c             | 30b             | 35a             | 25a             | 28c             | 21c            |
| PPBD                          | 70a             | 67c             | 61b             | 64c             | 53b             | 66a            |
| SBBD                          | 38b             | 47a             | 39c             | 42a             | 32b             | 34b            |

* Any two sums of ranks having different subscript letter(s) differ significantly ($p \leq 0.05$).
FUNDING

This work was financially supported by the USM Fellowship Scheme of the Institute of Postgraduate Studies, Universiti Sains Malaysia.

Notes
The authors declare no competing financial interest.

ABBREVIATIONS USED

BD, bulk density; BU, Brabender Units; CPBD, high-fiber bread containing chick pea bran; FAC, fat absorption capacity; FBBD, high-fiber bread containing faba bean bran; PPBD, high-fiber bread containing pigeon pea bran; SBBD, high-fiber bread containing soya bean bran; WBD, high-fiber bread containing wheat bran; W/CPB/CF, wheat/chickpea bran composite flour; W/FBB/CF, wheat/faba bean bran composite flour; W/HB, high-bran wheat flour; W/PPB/CF, wheat/pigeon pea bran composite flour; WRC, water retention capacity; W/SBB/CF, wheat/soya bean bran composite flour; WWF, whole wheat flour;

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