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Effect of barley flour addition on the physico-chemical properties of dough and structure of bread

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ABSTRACT

The effects of different percentages of barley flour (i.e. 0–25%) in wheat flours on the physico-chemical properties and structure of dough and bread were investigated. As the percentage of barley flour in mixed flour was increased, its protein and gluten contents decreased whereas the ash content and enzyme activity increased. The rheological characteristics of the four dough mixes were studied using Farinograph, Extensograph and Alveograph. The water absorption ($p < 0.01$) and stability ($p < 0.05$) decreased significantly as the percentage of barley flour increased, while no changes were observed in the extensibility and maximum heights. Significant differences were observed in the structural and physical properties as well as in the image analysis of breads. With the increase in the percentage of barley flour, the crumb apparent density decreased ($p < 0.1$) whereas the porosity (i.e., fraction to total volume) increased ($p < 0.1$). Overall, the shape and pore structure at 10% barley flour (W90B10) were similar to the pure wheat flour bread, while addition at 15 and 25% of barley flour (W85B15 and W75B25) showed more non-uniform and larger pores.

1. Introduction

Wheat is the most important cereal crop for bread making because of its supreme baking performance in comparison to all other cereals. However, other cereals can also be utilized in bread making e.g., barley that has a good potential for bread making due to its nutritional value (Newton et al., 2011). Therefore, utilizing barley in foods has high importance rather than just used in animal feed. The potential use of barley in bread making as well as its nutritional value was reviewed earlier (Sullivan et al., 2013). The nutritional value of bread could be increased if other cereal grains such as rye, barley and oats are incorporated into the bread formula. However, it could be a challenge to maintain the desired rheological properties of dough and bread.

Collar and Angioloni (2014) found that blending wheat with 40% of high β-glucan barley resulted in bread with high level of dietary fiber as compared to commercial barley and regular wheat bread. The wheat flour contains high amounts of protein and gluten as compared to barley flour, and these components play a significant role in baking performance. Therefore, mixing of wheat and barley flours at appropriate level to produce the desired properties of bread is a big challenge. In contrast to wheat flour, barley flour is rich in soluble fiber (β-glucan) (Koletta et al., 2014) and contains relatively high amounts of phenolic compounds, thus provides high antioxidant capacity (Demir et al., 2007; Hong et al., 2004). The total phenolic contents (TPC) of barley flour (148.3 mg GAE/100 g) was found to be higher than wheat (62.1 mg GAE/100 g) and oat (76.4 mg GAE/100 g) but less than rye (168.3 mg GAE/100 g) (Koletta et al., 2014). Therefore, the addition of barley in wheat flour for bread making could not only improve the nutritional and functional properties of bread but these breads may also be effective in lowering the total and LDL cholesterol in mildly hypercholesterolemic men and women (Behall et al., 2004).

Barley can also be used in other chemically leavened baked products like muffins, biscuits and cookies. However, little success was achieved when it was added to yeast leavened baked products (Gill et al., 2002). Although barley has long been known as a good source of fiber, the application of barley for bread making is very limited due to lack of its gluten content and poor rheological properties as compared to wheat (Sullivan et al., 2010). Pearled

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barley flour has been used in the preparation of many traditional foods in different countries all over the world (Chatterjee and Abrol, 1977). In Middle East and North African countries, barley is pearled, ground and used in soup formulations and flat bread making. Breads made of barley are commonly unleavened like griddle breads (e.g., bannocks). If leavened barley bread is desired, it is the best to mix barley with wheat and such mixtures have been used in European countries (Chatterjee and Abrol, 1977).

The effect of blending wheat and barley flours at different proportions on the dough characteristics and bread making were studied earlier (Alu'Datt et al., 2014; Dhingra and Jood, 2001, 2004; Ereifej et al., 2006; Koletta et al., 2014). The measured characteristics include sensory (e.g., appearance, color, textures, flavor), loaf volume and weight, mixing time, water absorption, gluten content, rheological properties and instrumental texture profile analysis. The addition of barley to wheat caused physical, chemical and rheological changes in the dough and bread characteristics. Dhingra and Jood (2001, 2004) concluded that blending wheat flour with 15% barley flour would produce bread of acceptable sensory properties. Ereifej et al. (2006) found that the addition of 15 and 30% of barley to wheat bread was accepted by consumer. Recently, Alu'Datt et al. (2014) found that 5 and 10% addition of barley was accepted by the consumers and trained panelist using descriptive test. In addition, the texture analysis and color measurement along with sensory results were similar to control sample (i.e., bread made only of wheat flour). Loaf volume, color and firmness were reported to depend on the barley variety and processing conditions, such as flour extraction rate and milling characteristics (Gill et al., 2002).

Research on breads produced using wheat and barley compensated with gluten are scanty (Dhingra and Jood, 2004; Koletta et al., 2014). More research is required to understand the effect of blending barley with wheat flours and their effects on dough rheological properties and bread structural characteristics (Sullivan et al., 2013). The aim of this research was to study the effect of gluten (3 g/100 g flour) compensated in mixed wheat and barley flours on the physico-chemical properties of flours, rheological properties of dough and structural characteristics of bread. In this study, different proportions of wheat (W) and barley (B) flours (W100B0, W90B10, W85B15 and W75B25) were used respectively.

2. Material and methods

2.1. Barley and wheat sample

Raw spring Australian barley variety (*Fathom*) and Canadian Western red spring wheat variety were received from Oman Flour Mills Company. The samples were inspected and examined for any infestation and impurities. Around 150 kg of each product (barley and wheat) was isolated and sealed in plastic containers and stored at 25 °C for further processing. The barley was first prepared using peeling machine and then milled to produce flour by separating the husk and endosperm from the ground barley.

2.2. Flour preparation and laboratory milling

Ten kg of wheat and barley samples were cleaned and conditioned to the moisture content of 15.5 g/100 g sample by adding water. The product was kept in plastic containers and covered for 24 h at 20 °C. The Buhler laboratory mill with six rolls (MLU-202. Buhler-Uzwil, Switzerland) was used for milling with 15 min warming time. At the end of 3 stages milling operation, the bran was separated from the ground wheat and barley using sieve of size 475 μm, while flour was collected from the six rolls and was passed through the sieve of size 132 μm.

2.3. Dough formulation

Dough was prepared from 2 kg of mixed flours with different percentages of wheat and barley flours as: 100:0 (W100B0); 90:10 (W90B10); 85:15 (W85B15); and 75:25 (W75B25), respectively. Ascorbic acid (flour oxidation agent, 0.15 g) and bread improver (combination of ascorbic acid and α-amylase enzymes, 2 g) were added for the development of gluten networks. Accordingly, wheat gluten was added as 3 g/100 g flour to compensate the expected deficiency of gluten in the wheat and barley mixtures. Salt (20 g) and yeast (20 g) were also added to the flour mixtures.

2.4. Bread-making method

Straight dough method No.10–09.01 (AACC, 1999) was used for bread-baking process. The conditions of dough preparation were optimized as: mixing time (i.e., 5 min), oxidation level (i.e., 0.15 g per 2 kg flour), proofing time (i.e., 90 min) and temperature and humidity (i.e., 45 °C, 63% relative humidity). These conditions were kept constant for all dough formulations. Water absorption was also optimized and balanced considering in accordance with all four different mixers. The optimum absorption rate varied from 65 to 72% based on the mixture. The baking temperature and time were kept at 190 °C and 28 min, respectively. Dough of 420 g was baked in a rotary oven (Sveta, Sweden).

2.5. Chemical analysis

The chemical composition of wheat and barley samples was determined using the American Association of Cereal Chemists methods (AACC, 1999). Moisture (44-15A), protein (46-12, Kjeldahl method) and ash contents (08-18) of samples were determined. The Falling number was measured according to 56-81B method (AACC, 1999). All measurements were carried out in triplicates.

2.6. Rheological analysis

Water absorption, dough development, stability and softening of the dough during mixing were measured using the Farinograph instrument (Brabender, Germany). The sample preparation was done according to the AACC procedure (54-21). The maximum resistances for strength and dough extensibility were studied using the Extensograph instrument (Brabender, Germany). The experiment was run according to AACC-54-10 method. The resistance of dough to extension and the extent to which it can be stretched was measured using Alveograph machine (Chopin, France). The experiment was run according to AACC 54-30A method. The measured parameters were: maximum over pressure (P), average abscissa at rupture (L) and energy of dough (W). All tests were carried out in triplicate for each formulation.

2.7. Structure analysis

2.7.1. Bread image analysis

Bread was taken out from oven after baking and kept for cooling at room temperature (20 °C). The whole bread was sliced transversely with a slicing machine (APV, Germany). The images were captured using a color camera (CANON EOS 1100D, EF-S 18-55 III, Canon Inc., Taiwan) with a resolution of 4272 × 2848 pixels. Before imaging, the camera was standardized by customizing the white balance by a gray card (model: Digital Gray Kard XL, DGK Color Tools, USA) with 18% reflectance (Al-Rahbi et al., 2013; Valous et al., 2009). The camera was located at 20 cm overhead on the sample platform to obtain the best image of the samples of bread slices throughout the experiment. The samples were illuminated with