Journal of Cereal Science 60 (2014) 520–525

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

Physicochemical characterization of whole-grain wheat flour in a frozen dough system for bake off technology

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ARTICLE INFO

Article history:
Received 3 April 2014
Received in revised form
17 July 2014
Accepted 6 August 2014
Available online 16 September 2014

Keywords:
Whole-grain wheat flour
Frozen dough
Bread-making
Bake-off technology

ABSTRACT

Whole-grain wheat flour was utilized in a frozen bread dough system and its functional and baking performances were characterized for bake off applications. Whole-grain wheat flour high in dietary fibers (11.84%) exhibited greater water hydration properties than white wheat flour at room temperature. The opposite results were however observed upon starch gelatinization which could be correlated to the reduced pasting properties of the whole-grain wheat flour. Decreased dough development and stability times were measured in whole-grain wheat dough that also exhibited reduced extensibility and resistance to extension. The lower loaf volume and firmer crumb texture of whole-grain bread were observed as compared with white bread. Frozen storage of dough for 4 weeks had a negative effect on the loaf volume and firmness of the bread. The bread samples prepared with white and whole-grain frozen dough exhibited a significantly lower loaf volume by 17.9 and 8.8% and firmer texture by 39.9 and 28.8%, respectively. Thus, the deterioration of the two bread qualities appeared to be less dependent on the frozen storage in the whole-grain dough system. The use of whole-grain flour produced bread with enhanced antioxidant activity which was not affected by the storage of the dough in the frozen state.

1. Introduction

Whole-grains are composed of the intact, ground, cracked or flaked caryopsis and include three principal components (starch endosperm, germ, and bran) in the same proportion to the intact grains (De Moura et al., 2009). Thus, whole-grains contain all naturally occurring and essential substances of the entire seed. Consequently, they are regarded as an excellent source of nutritional and health-functional ingredients. Thereby, a whole-grain health claim on food labels has been approved by the US FDA for the possible risk reduction of heart disease and some cancers when the food contains at least 51% whole-grain ingredients and meets other requirements such as dietary fiber level and fat content (US FDA, 2009). With this trend, there has been currently great interest in whole-grain foods due to the increasing public awareness of the relationship between health and diets. The whole-grain market is growing at a remarkable rate and estimated to reach more than 24 billion US dollars by 2015 (Mozaffarian et al., 2013).

The scientific research emphasis of the whole-grains has been placed primarily on their physiological health benefits such as the reduced risk of cardiovascular disease, type II diabetes, and cancers (Okarter and Liu, 2010). From the food processing point of view, there have been several preceding studies where whole-grain flour was used to produce pasta (Manthey and Schorno, 2002; Villeneuve and Gélinas, 2007; West et al., 2013) and bread (Gélinas and McKinnon, 2011). Specifically, in the case of bread, most of the studies placed their research focus on the improvement of bread quality by enzymatic treatments (Jaekel et al., 2012; Shah et al., 2006) and food additives (Boz et al., 2010; Flander et al., 2007). However, the practical applications of whole-grains to a wider variety of food products have still been limited.

Baking industry is currently facing a challenge of technological innovations. Specifically, the segment of 'Bake Off' products that use frozen dough is one of the fastest growing areas at the industrial level due to their time- and labor-saving advantages (Le-Bail et al., 2010). However, the use of frozen dough causes performance disadvantages of baked products. Therefore, a number of studies have been performed in order to minimize the quality loss of bread made from frozen dough. Most of the studies have been dedicated to controlling various processing variables such as freezing rate, frozen storage conditions, and pre-fermentation (Le-

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http://dx.doi.org/10.1016/j.jcs.2014.08.006
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Bail et al., 2010; Yi and Kerr, 2009). In addition, a variety of food ingredients including hydrocolloids and emulsifiers were evaluated as a frozen dough bread improver (Matuda et al., 2005; Ribotta et al., 2004). However, there is still a lack of fundamental information on the physicochemical properties of frozen dough for practical applications. Moreover, any preceding studies have not been carried out to investigate the bread-making performance of whole-grain flour in a frozen dough system to our best knowledge. Furthermore, it is still necessary to provide the fundamental physicochemical information of whole-grain flour for its better understanding in a food system.

In this study, the physicochemical properties of whole-grain wheat flour were characterized and compared with those of white wheat flour. They were also used to prepare frozen bread dough whose quality attributes before and after baking were evaluated for the bake off technology.

2. Experimental

2.1. Materials

White (power high gluten flour, Pendleton Flour Mills, Chattanooga, TN, USA) and whole-grain wheat flours (spring whole wheat flour, ADM Milling Co., Enid, OK, USA) were obtained from a commercial source. White wheat flour was used as the control sample. All the chemicals and reagents used in this study were of analytical grade.

2.2. Physicochemical characterization of white and whole-grain wheat flours

2.2.1. Chemical compositions

The proximate chemical compositions of white and whole-grain wheat flours (ash, protein, fat, and moisture) were determined based on the AOAC-approved methods (AOAC, 2005). The enzymatic-gravimetric method was used for analyzing the contents of total, insoluble, and soluble dietary fibers in the white and whole-grain wheat flours (AOAC, 2005).

2.2.2. Water hydration properties

The water hydration properties of white wheat flour, whole-grain wheat flour, and their mixture (50:50) were characterized at two different temperatures. Each flour sample (0.5 g) was mixed with distilled water (30 mL) at 25 and 100 °C for 30 min. After centrifugation at 15,000 *g* for 20 min, the supernatant was oven-dried at 105 °C. Three water hydration parameters – water absorption index, water solubility, and swelling power, were calculated based on the method of Heo et al. (2013).

$$\text{Water absorption index} = \frac{\text{wet sediment weight}}{\text{dry sample weight}}$$

$$\text{Water solubility(WS, \%)} = \frac{\text{dry supernatant weight}}{\text{dry sample weight}} \times 100$$

$$\text{Swelling power} = \frac{\text{wet sediment weight}}{[\text{dry sample weight} \times (1 - \text{WS(\%)}/100)]}$$

2.2.3. Dough mixing properties

The mixing properties of white wheat flour, whole-grain wheat flour, and their mixture (50:50) were investigated by using Farinograph (Brabender, Duisburg, Germany) according to the AACC international standard method (54–21) (AACC, 2000). The flour sample was loaded into a mixing bowl and distilled water was injected for the optimum dough consistency (500 BU). The water absorption and development/stability times of the dough during mixing were determined from the obtained farinogram.

2.2.4. Pasting properties

A starch pasting cell attached to a controlled-stress rheometer (AR1500ex, TA Instruments, New Castle, DE, USA) was applied to investigate the pasting properties of white wheat flour, whole-grain wheat flour, and their mixture (50:50). Distilled water was added to each flour in an aluminum canister to produce a 28 g suspension (10.7%, w/w) which was subjected to the following heating–cooling cycle: equilibration at 50 °C for 1 min, heating to 95 °C at a rate of 12 °C/min, temperature holding at 95 °C for 2.5 min, cooling to 50 °C at a rate of 12 °C/min, and final temperature holding at 50 °C for 5 min.

2.3. Application of white and whole-grain wheat flours to frozen dough bread

2.3.1. Bread-making

Bread samples were prepared with white wheat flour, whole-grain wheat flour, and their mixture (50:50) according to the AACC method (10–10.03) with modifications (AACC, 2000). The bread formulation consisted of 100% wheat flour (14% moisture basis), 2% instant dry yeast (Lesaffre Yeast Col, Milwaukee, WI, USA), 6% sugar (The Amalgamated Sugar Col, Boise, ID, USA), 1.5% salt (Morton Inc., Chicago, IL, USA), 3% shortening (Criso, The J.M. Smucker Co., Orrville, OH, USA), and 50 mg/kg ascorbic acid (J.T. Baker, Phillipsburg, NJ, USA). The optimum water absorption and dough development time were determined from the Farinograph results. Dough was mixed in a Swanson mixer (National Mfg. Co. Lincoln, NE, USA), divided into 150 g pieces, and rounded. After freezing at −40 °C, the dough samples were stored in plastic bags at −20 °C for 4 weeks. After 2 and 4 weeks of the frozen storage, the frozen doughs were placed at room temperature for 1 h and then transferred to a proofing cabinet (30 °C, 85% relative humidity). The dough samples were punched with a dough sheeter (National Mfg. Co. Lincoln, NE) after 105 and 155 min respectively and molded, followed by panning. After proofing for 1 h (30 °C, 85%), they were baked at 215 °C for 24 min and then allowed to cool down at room temperature for 2 h.

2.3.2. Extensional properties of dough

Extensograph (Brabender, Duisburg, Germany) was applied to investigate the extensional properties of bread dough samples prepared with white wheat flour, whole-grain wheat flour, and their mixture (50:50). Cylindrically-molded dough (150 g) was rested in a cabinet at 30 °C for 45 min, placed in an extensograph dough holder, and stretched to measure its maximum extensibility and resistance to extension.

2.3.3. Loaf volume of bread

The loaf volume of bread was measured at room temperature by using a laser-assisted volumeter (TexVol, Viken, Sweden).

2.3.4. Firmness of bread

The firmness of bread was determined by using a Texture analyzer (Texture Technologies Co., Scarsdale, NY, USA). A cylindrical probe (25 mm diameter) was lowered to compress a bread slice (25 mm thickness) at a speed of 2 mm/s by 60% strain. The maximum force required to accomplish a given deformation during the compression was determined from the resultant force–time curves.

2.3.5. Antioxidant activities

The antioxidant activity of the bread made from frozen dough was determined by 2,2-azino-bis-3-ethylbenzothiazoline-6-