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Effect of mechanically damaged starch from wheat flour on the quality of frozen dough and steamed bread

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ABSTRACT

The influence of damaged starch (DS) on the quality of frozen dough and steamed bread were investigated. Characterization of the farinographical properties showed that DS levels affected water absorption, development, weakness, falling number and gluten index. Flour viscosity profiles indicated that pasting temperatures increased, but peak viscosity, low viscosity, breakdown, final viscosity and setback increased and then decreased with increasing amounts of DS. Compared to leavened dough, unleavened dough had significantly higher peak times, of T_{21} and T_{22}, and was also affected by DS concentration. Steamed bread had a higher specific volume, relatively lower hardness, exhibited more whiteness, and a higher degree of gumminess and chewiness with higher DS levels. We compared two methods of making steamed bread and assessed the quality of the product. We found that an appropriate DS content improved the quality of frozen dough and steamed bread. This study provides the basis for future development and improvements to methods for making frozen dough products.

1. Introduction

Steamed bread is a staple fermented food in China, made of wheat flour, water and yeast. Dough made of fermented flour is shaped and then steamed, which enhances the taste and digestibility of the steamed bread. Steamed bread has higher nutritive value and is healthier, due to inhibition of the Maillard reactions, a nonenzymatic reaction between sugars and proteins that occurs upon heating, no requirements for preservatives, and a lack of formation of acrylamide. However, steamed bread has a relatively short shelf life.

Frozen dough has become increasingly popular for industrial use. Two kinds of frozen dough are available, differing in whether or not the fermentation has occurred prior to freezing. Non-fermented frozen dough is fermented after thawing, and dough fermented before freezing is referred to as pre-fermented frozen dough (Huang, Wan, Huang, Rayas-Duarte, & Liu, 2011). The dough can be manufactured on a large scale, off-site, and then shipped to local restaurants or retail operations for on-site baking, saving both equipment and labor costs. Frozen dough allows constant availability of fresh products, and provides consistent and uniform quality, which makes frozen dough an appealing option for the industrial production of steamed bread (Huang, Wan, Huang, Rayas-Duarte, & Liu, 2011; Räsänen, Blanshard, Mitchell, Derbyshire, & Autio, 1998). However, frozen dough requires a longer proof time and produces bread with lower specific volume and a texture that differs from freshly baked bread (Eckardt et al., 2013; Jia et al., 2012; Meziani et al., 2012). The viscoelastic property of dough is also decreased with the freezing and thawing processes of dough, resulting in changes to the final product (Kim, Huang, Du, Pan, & Chung, 2008).

Damaged starch (DS) refers to small particles of starch broken away from the main starch granules in wheat during milling. These smaller particles are more easily used by yeast for gas production, can hydrate more easily, and are more susceptible to enzymatic hydrolysis during the process of dough preparation (Barrera, Perez, Ribotta, & Leon, 2007; Liu et al., 2014; Mulla, Bharadwaj, Annapure, & Singhal, 2010). Furthermore, with enhanced water adsorption, the DS forms a gel more easily, enhancing the dough extensibility (Zhu, 2014). The level of starch damage therefore affects both the water absorption and dough mixing properties of flour (Ghodke, Ananthanarayan, & Rodrigues, 2009). Moderate amounts of DS are good for breadmaking because of these effects to improve hydration and promote fermentation activity (Boyacı, Williams, & Köksel, 2004). However, higher levels of DS can increase the reducing sugar content of the resultant flour (El-Porai, Salama, Sharaf, Hegazy, & Gadallah, 2013). Excessive DS can also allow too much water to be absorbed and can lead to accelerated enzymatic action, resulting in sticky dough, strong proofing,

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less bread volume, and an undesirable red crust color (Barak, Mudgil, & Khatkar, 2014; Ghodke et al., 2009; Hatcher, Bellido, & Anderson, 2009). Therefore, the amount of DS in flour is a key contributor to the quality of dough and wheat-based products.

For the most part, non-fermented frozen dough is used in industrial baking. However, pre-fermented frozen dough has some advantages in terms of reduced need for yeast viability after frozen storage, less time-consuming production after freezing and less expensive equipment needed for on-site baking (Huang et al., 2011). Only a few studies have been carried out to study the characteristics of frozen dough, and to the best of our knowledge there are no reports published on comparisons of non-fermented frozen dough with pre-fermented frozen dough and no reports of how the properties of these doughs are affected by DS. Which kind of frozen dough is suitable for steamed bread is also needed to be studied in detail. To address this need, we sought to evaluate the effects of DS levels on the quality of frozen dough and steamed bread and determine the optimal type of frozen dough for steamed bread.

2. Materials and methods

2.1. Materials

Commercial wheat flour (13.4% moisture, 0.48% ash, 16.4% protein, 392 s falling number, 57.1% water absorption) and active dry yeast (Angel brand, Hubei, China) were procured from a local market. All other reagents and chemicals used were of analytical grade.

2.2. Chemical analysis

Moisture, ash and protein were determined by Approved methods 44-15A, 08-01, and 46-12, respectively (AACC, 2000). DS content was determined by SDmatic by Chopin Technologies (Paris, France; Medcalf & Gilles, 1965). A solution of 120 ml of distilled water, 3 g boric acid, 3 g potassium iodide and one drop of sodium thiosulfate was placed in the reaction bowl. 1 g of flour was weighed accurately and was placed in the spoon in the SDmatic and the arm of the SDmatic was folded down. After 6 min of the SDmatic cycle, the damaged starch content of the flour sample was noted. Farinograph test was performed according to the standard AACC Method 54-21 (AACC, 2000) (Brabender, Duisburg, Germany). Farinograph water absorption was defined as the amount of water (%, on 14% moisture flour basis) required to achieve a dough consistency of 500 PU (Promylograph units).

2.3. Flour pretreatment

Batches of 200 g flour were treated in a planetary ball mill. In brief, the flour was milled at 200 r/min for 30 min, 300 r/min for 30 min, 200 r/min for 60 min, and 300 r/min for 60 min, corresponding to 12.2, 15.7, 21.9 and 30.0 UCDc (Corrected Chopin Dubois Units of DS), respectively.

2.4. Frozen dough and steamed bread preparation

Batches of 100 g pretreated flour (14.0% moisture base), 1 g active dry yeast and variable amounts of water were mixed at low speed, for 5 min, using a Hobart mixer A-120 (The Hobart Manufacturing Company, Tory, Ohio). Variable water content was about 80% of the Farinograph water absorption. The dough was sheeted at 3.5 mm 15 times (HL-110, Guangdong Hengji Co. Ltd., Guangdong, China), rolled into a long, cylindrical shape by hand, divided into 100 g pieces, and processed in two ways. In the first method, the pieces were immediately frozen at −38 °C for 2 h, and then transferred to −18 °C for 24 h, as non-fermented frozen dough. The dough was then thawed at ambient temperature, and then leavened in a fermenting box for 1 h at 38 °C and 85% RH. The dough was steamed for 30 min in a steamer with boiling water (method A). In the second method, the pieces were leavened at 38 °C and 85% RH for 40 min, and then frozen using the same condition as above, for pre-fermented frozen dough. After that, the dough was thawed and steamed (method B). Both methods were performed and the fresh steamed bread was covered with gauze and cooled at room temperature for 60 min before quality evaluation.

2.5. Pasting properties

Pasting properties of the samples were determined with a Rapid Visco Analyzer (RVA), using AACC methods (2000). The RVA parameters were obtained from flour–water suspensions. The flour slurry (10%, W/W) was equilibrated at 50 °C for 1 min, and then heated up to 95 °C at a rate of 6 °C/min and a stirring rate of 960 rpm. It was held at 95 °C for 5 min, and finally cooled to 50 °C at a cooling rate of 6 °C/min. Pasting temperature, peak viscosity, low viscosity, final viscosity, break down, and setback were obtained from the pasting curve. Analyses were performed in triplicate.

2.6. Nuclear magnetic resonance (NMR)

After thawing, the non-fermented and pre-fermented frozen dough, were immediately put into a Niumag Desktop Pulsed NMR Analyzer (MicroMR-CL-I, Shanghai Niumag Electronics Technology Co. Ltd., Shanghai, China) for water migration determination. Transverse relaxation (T_2) was measured using the CPMG pulse sequence. The number of points, echos, and scans was 163,238, 2000, and 4, respectively. The relaxation time decayed was 1 s. The CPMG data were fitted by T2-fit program (Ningbo Jianxin Machinery Co., Ltd., Ningbo, Zhejiang, China).

2.7. Steamed bread evaluation

Steamed bread volume was determined according to the rapeseed displacement method (AACC, 2000). The specific volume (ml/g) of the bread was calculated as: bread volume/bread weight. Color was determined by a Minolta CN-508i spectrophotometer (Minolta, Co. LTD, Tokyo, Japan). Hardness, elasticity, cohesiveness, gumminess, chewiness and resilience were measured using a Texture Analyser (Model: TA-XT2i, Stable Microsystems, Surrey, UK), equipped with a 25 mm diameter aluminum cylindrical probe with pre-test speed 3 mm/s, test speed 1 mm/s, and post-test speed 5 mm/s. The deformation level was 50% of the original height.

2.8. Statistical analysis

The data were statistically treated by variance analysis, and the significant differences between two samples were analyzed by Duncan's test with SPSS software (version 15.0, SPSS Inc., Chicago, IL, USA).

3. Results and discussion

3.1. Farinographical properties

Table 1 shows the physical properties of wheat flour influenced by starch damage. Water absorption increased significantly from 57.1 to 64.5, as DS increased from 9.3% to 30%, consistent with a higher water retention capacity of DS compared to native wheat