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The contribution of glutenin macropolymer depolymerization to the deterioration of frozen steamed bread dough quality

Pei Wang [a,b], Tung-Ching Lee [a,*], Xueming Xu [b,*], Zhengyu Jin [b]

[a] Department of Food Science, Rutgers, The State University of New Jersey, 65 Dudley Road, New Brunswick, NJ 08901, USA
[b] State Key Laboratory of Food Science and Technology, School of Food Science and Technology, Synergetic Innovation Center of Food Safety and Nutrition, Jiangnan University, 1800 Lihu Avenue, Wuxi 214122, Jiangsu Province, PR China

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ABSTRACT

Depolymerization of glutenin macropolymers (GMP) widely exists in the frozen dough with little effort in elucidating its effects on steamed bread quality. To clarify this, GMP was fractionated from wheat flour and reconstituted to yeast and chemical leavened dough (YLD/CLD). Results showed that with supplementary GMP fraction, depolymerization degree was alleviated in frozen dough. The bread quality loss from freezing was partially counteracted along with better preserved GMP content. Both of dough elasticity and gas retention capability were enhanced in GMP-enriched frozen dough. Gassing power in frozen YLD decreased while remained constant in CLD. Addition of GMP did not affect the gassing power, which allowed interpreting the improved bread qualities from the enhanced dough elasticity and gas retention capability. Based on the improved facts of frozen steamed bread dough quality with additional GMP fractions, this study revealed the pivotal role of GMP depolymerization on the frozen steamed bread dough quality.

1. Introduction

Chinese steamed bread (CSB) is a traditional Chinese staple food and representing about 40% of the wheat consumption in China (Kim, Huang, Zhu, & Rayas-Duarte, 2009). The basic formulation of CSB includes wheat flour, water and leaveners (yeast or chemical leaveners). The steaming procedure renders the product with a soft, moist and dense crumb and a thin, smooth, white skin rather than the brown crust of traditional western baked bread. Moreover, the lower steaming temperature better preserved the protein quality of wheat flour than baked bread (Gotthold & Kennedy, 1964; Tsen, Reddy, & Gehrke, 1977). This is pivotal for the national nutrition due to the staple role of CSB.

With the rapid urbanization in China, the industrialization of CSB is very promising. Utilization of freezing technology largely extends shelf-life of dough, which allows its production at large scales. The bakery industry is a typical example of being exploited by freezing technology in the western countries. Meanwhile, CSB has a relatively shorter shelf-life and higher propensity to staling due to its higher moisture content as compared with baked bread. This also makes frozen dough more appealing for the industrialization of CSB (Huang, Wan, Huang, Rayas-Duarte, & Liu, 2011). Despite the many advantages from the frozen dough technology, the dough gradually deteriorates and leads to poor loaf volume and significant textural deterioration. Loss of yeast activity and gluten network disruption are widely suggested to be the main inducing factors in yeast leavened dough (YLD). Chemical leaveners are an alternative approach and particular useful for dough that is subject to frozen storage. Because carbon dioxide production capabilities in chemical leavened dough (CLD) are not to be affected by the prolonged frozen storage (Bellido, Scanlon, Sapirstein, & Page, 2008). The CLD system could eliminate the gassing power loss and thus allow to directly investigating the relationship between componential alterations and the frozen bread dough quality.

On the other hand, gluten deterioration in frozen dough is still a field of active research with a number of avenues dedicated to alleviate this phenomenon (Selomulyo & Zhou, 2007). However, current approaches are empirical rather than based on the specific principles. This is due to the complex structure and wide molecular weight distribution of gluten polymers as well as the convoluted consequences induced by freezing which involves conformational rearrangement, water redistribution, etc. Among them, previous studies widely suggested depolymerization of glutenin macropolymer (GMP) in frozen dough was an important actuator to the baked bread quality loss, which originated from two points in general: (a). GMP is highly polymerized glutenin polymers which is

* Corresponding authors.
E-mail addresses: whiteblair1991@yahoo.com (P. Wang), lee@aesop.rutgers.edu (T.-C. Lee), xmxu@jiangnan.edu.cn (X. Xu), Jinlab2008@yahoo.com (Z. Jin).

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SDS-insoluble and contributes the most to the dough physical properties and the baked bread qualities from the statistical correlation studies (Wang, Zhao, & Zhao, 2007; Weegels, Hamer, & Schofield, 1996); (b). GMP depolymerization occurred along with the freezing and the diminished GMP content was thus supposed to contribute to the dough deterioration (Ribotta, León, & Añón, 2001; Sharadanant & Khan, 2006). However, the detailed way of how the GMP depolymerization contributed to the bread quality remained far from being manifested. Therefore, there have been ramining the issue of reliability of the contribution of GMP to the frozen dough quality. In addition, literature on the frozen dough for steamed bread was quite limited, leaving a major gap between the steamed bread quality and the GMP depolymerization. In the previous studies, GMP content was positively correlated to the steamed bread quality which was similar as baked bread (Zhang et al., 2008). Compared with the indirect statistically correlation studies, fractionation and reconstitution methodology is one of the most direct avenue to determine how varying certain fractions would change the quality and therefore provide insight of its specific functionality (Melnyk, Dreisoerner, Marcone, & Seetharaman, 2012).

Against this background, the primary objective of the current study was to facilitate the identification of the depolymerization effects of GMP on the steamed bread qualities made from frozen dough. Firstly, GMP was fractionated from wheat flour, reconstituted to the dough and subjected to freeze/thaw cycles. Consequently, the GMP content, steamed bread quality indices, rheological and gassing properties of dough were evaluated and compared. In addition, CLD was also employed to eliminate the gassing power loss compared with YLD, which would provide a further improved understanding on the contribution of GMP depolymerization to the frozen dough quality.

2. Materials and methods

2.1. Materials

All purpose flour (10% protein, 73% carbohydrate, 12% moisture, General Mills Inc., Minneapolis, MN), Fleischmann's® ActiveDry™ yeast (ACH Food Companies, Inc., Cordova, TN) and single-acting chemical leavener (sodium acid pyrophosphate, corn starch, sodium bicarbonate. Leavening action is desired at steaming procedure, Red Star®, Wisconsin) for making dough were purchased from a supermarket. Deionized water was used throughout the experiment. All the chemicals were of analytical grade unless otherwise specified.

2.2. Extraction of GMP

The extraction of GMP was performed according to Don, Lichtendonk, Plijter, and Hamer (2003). The flour (50 g) was extracted twice with 1 L of a 0.05 M sodium phosphate buffer (pH 6.8) containing 2.0% sodium dodecylsulphate (SDS) and once with water for 60 min at room temperature. After centrifugation at 10,000*g* for 10 min, the supernatant was decanted and the gel-layer collected as GMP. The GMP was further freeze-dried and grounded by a grinder to pass through a 100-mesh sieve.

2.3. Frozen dough preparation

Chinese steamed bread was prepared according to GB/T 17320-1998 (China State Bureau of Technical Supervision, 1998). The basic recipe for YLD contained 450 g flour, 5 g yeast and 245 g water and CLD was made up of 450 g flour, 27 g chemical leavener and 280 g water. A level of 1% GMP fractions (dry protein basis) were incorporated to the formulation (denoted as GMP-enriched dough). All the ingredients were mixed and kneaded in a mixer (C-100 Mixer, Hobart Corporation, Ohio, USA) at 60 rpm for 2 min and at 120 rpm for 3–5 min to achieve complete development. Mixing time was carefully optimized to achieve smooth dough with the optimum steamed bread character according to the preliminary assays. The dough was divided to 80 g pieces, molded, followed by freezing at −18 °C for 48 h and were then thawed in a 4 °C refrigerator for 12 h as one freeze/thaw cycle. After three freeze/thaw cycles, a batch of dough was freeze dried and the other batch was used for characterization of dough and bread qualities.

2.4. Size-exclusion high performance liquid chromatography (SE-HPLC)

SE-HPLC was performed on a Waters 600E HPLC system equipped with Dionex Bio LC AD25 UV/vis detector (Dionex Corp., Sunnyvale, CA). Freeze-dried dough samples (10 mg) were extracted with 1 mL of a 0.05 M sodium phosphate buffer (pH 6.8) containing 2.0% sodium dodecylsulphate (SDS) for 60 min at room temperature. After centrifugation at 10,000*g* for 5 min, 20 μL of the supernatant was loaded on a Zorbax GF-450 column (Agilent, USA). The elution solvent was 0.05 M sodium phosphate buffer (pH 6.8) containing 0.2% SDS. The flow rate was 0.7 mL/min. The thermostat was set at 30 °C and the elution was detected at 214 nm. All extractions were performed at least in triplicate. The soluble polymers, monomers and insoluble GMP fraction (%) were calculated from the relative peak areas and expressed as:

$$\text{Polymers}\ (\%) = \frac{A_p}{A_r} \times 100\%$$

$$\text{Monomers}\ (\%) = \frac{A_m}{A_r} \times 100\%$$

$$\text{GMP}\ (\%) = 100\% - (\text{Polymers} + \text{Monomers})$$

where A_p and A_m is the peak area of the soluble polymeric and monomeric proteins, A_r is the peak area of total reduced proteins which was extracted with the SDS buffer in the presence of 1.0% dithiothreitol (DTT) (Wang et al., 2014).

2.5. Steamed bread making procedure and analysis of bread qualities

Dough pieces were fermented at 30 ± 1 °C under 80 ± 5% relative humidity until the optimum height. The dough was steamed in the tray above boiling water for 30 min. After steaming, the bread was cooled to room temperature and packed into plastic bags. Bread was left at ambient temperature and analyzed within 12 h.

The method for measuring steamed bread properties was adopted from GB/T 17320-1998 and GB/T 21118-2007 (China State Bureau of Technical Supervision, 1998, 2007) with slight modification. Bread was weighed and loaf volume was measured by rapeseed replacement. Water content was measured using a Denver Moisture Analyzer IR-200 (Denver Instrument, Bohemia, NY). Firmness was measured by TA.XT2i (Stable Micro Systems, Ltd., London, UK) using a 40 mm cylindrical acrylic probe. Steamed bread was sliced from the center to obtain uniform slices of 25 mm thickness. The bread slices were compressed at a speed of 1.7 mm/s to a total distance of 10 mm (40% strain) and the firmness (g) was recorded at 25% strain. At least six slices were analyzed. For the image analysis, four slices (thickness 25 mm) were cut from the center of bread samples. A single 50 × 30 mm field of view in the center of each slice was captured for each image analysis.