Food Chemistry 200 (2016) 117–124

Contents lists available at ScienceDirect

Food Chemistry

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

Impact of water extractable arabinoxylan from rye bran on the frozen steamed bread dough quality

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ARTICLE INFO

Article history:
Received 11 October 2015
Received in revised form 4 January 2016
Accepted 8 January 2016
Available online 8 January 2016

Keywords:
Water extractable arabinoxylan
Steamed bread
Ice crystallization
Yeast
Gluten

ABSTRACT

Impact of water extractable arabinoxylan from rye bran on frozen steamed bread dough quality was investigated in terms of the bread characteristics, ice crystallization, yeast activity as well as the gluten molecular weight distribution and glutenin macropolymer content in the present study. Results showed that water extractable arabinoxylan significantly improved bread characteristics during the 60-day frozen storage. Less water was crystallized in the water extractable arabinoxylan dough during storage, which could explain the alleviated yeast activity loss. For all the frozen dough samples, more soluble high molecular weight (Mw ≈ 91,000–688,000) and low molecular weight (Mw ≈ 91,000–16,000) proteins were derived from glutenin macropolymer depolymerization. Nevertheless, water extractable arabinoxylan dough developed higher glutenin macropolymer content with lowered level of soluble low molecular weight proteins throughout the storage. This study suggested water extractable arabinoxylan from rye bran had great potential to be served as an effective frozen steamed bread dough improver.

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 is wheat flour, water and leaveners (yeast or chemical leaveners). Sourdough starter is sometimes used instead of yeast. Unlike the baking process, the steaming process results in bread with a soft, moist crumb and a thin, smooth, white skin rather than the brown crust of traditional western baked bread. The low steaming temperature better preserved the protein quality of wheat flour than baked bread, which was suggested to be correlated with the preserved lysine availability (Gotthold & Kennedy, 1964; Tsen, Reddy, & Gehrke, 1977). This is pivotal for the national nutrition due to the staple role of CSB. Nutritional properties have drawn increasingly national attention with the rapid development of living standard in China. Fortification of CSB with dietary fiber is one of the approaches to improve the nutritional quality (Lan et al., 2013). Scientific research emphasizes the utilization of whole-grains has been placed primarily on their physiological health benefits such as the reduced risk of cardiovascular disease, diabetes, and cancers. Arabinoxylan (AX) is the dietary fiber which mainly enriches in cereal bran, particularly in the rye grains. AX is also considered as one of the main functional components for the health benefits of whole-grain bread. Two different classes of AX exist in wheat. They are the water-extractable AX (WEAX) and water-unextractable AX (WUAX). WEAX are loosely bound to the cell wall surface while WUAX are retained in the cell wall by covalent and non-covalent interactions with AX and protein, lignin and cellulose (Mendis & Simsek, 2014). The improved baked bread qualities with addition of AX is mainly attributed to the WEAX fraction, especially for the WEAX from the rye grains (Denli & Ercan, 2001). Rye grains contained more high molecular weight WEAX than the wheat and previous studies demonstrated that WEAX with higher molecular weight showed superior improved loaf volume and textural properties (Biliaderis, Izydorczyk, & Rattan, 1995; Ragaee, Campbell, Scoles, McLeod, & Tyler, 2001). On the other hand, WUAX, either have no significant effect or negative effect on the bread qualities due to their disruption of gluten network during mixing (Wang et al., 2003).

The industrialization of CSB is very promising with the rapid urbanization in China. Utilization of freezing technology largely extends shelf-life of dough and 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

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http://dx.doi.org/10.1016/j.foodchem.2016.01.027
0308-8146/

due to its higher moisture content as compared with baked bread. This also makes frozen dough more appealing for the industrialization of CSB. Despite the many advantages from the frozen dough technology, the dough deterioration during frozen storage is a remarkable and notorious phenomenon, leading to poor loaf volume and significant deterioration in textural properties (Wang, Jin, & Xu, 2015; Wang, Tao, Jin, & Xu, 2015).

Therefore, a number of studies conducted to minimize the quality loss of frozen dough were mainly focused on improving freezing process as well as the dough formulation (Rouille, Le Bail, & Courcoux, 2000; Yi & Kerr, 2009). A variety of food ingredients such as emulsifiers and hydrocolloids were utilized as frozen dough improvers (Selomulyo & Zhou, 2007). Recently, whole-grain dough as a source of AX showed more resistance to the frozen storage compared with the dough made from common white flour, indicating a possible role of some fiber components (e.g. AX) in minimizing water redistribution in the dough system and therefore lessening adverse modifications to the gluten structure (Adams, Ragaee, & Abdelaal, 2015; Bae, Lee, Hou, & Lee, 2014). However, the detailed mechanism remained far to be manifested. Meanwhile, with the supplement of pentosanase in frozen dough, smaller AX fractions from the enzymatic action were suggested to have a great potential in preserving the baked bread characteristics (Steffolani, Ribotta, Perez, Puppo, & León, 2012). Therefore, against this background, the objective of this study was to explore the WEAX as a dough improver in preserving the steamed bread quality made from frozen dough. The mechanism of the WEAX functionality in the frozen dough was also evaluated from the aspects of ice crystallization, yeast and gluten properties.

2. Materials and methods

2.1. Materials

Commercial steamed bread flour (10% protein, 74% carbohydrate, 13% moisture) and active dry yeast (Angel brand, Hubei, China) were purchased from a local supermarket. Deionized water was used throughout the experiment. All the chemicals were of analytical grade unless otherwise specified. Rye bran were obtained from YuTian Co., Ltd. (Shandong, China), alpha-amylase (Termamyl 120 L), amyloglucosidase (AMG 300 L) were purchased from Novozymes (Bagsvaerd, Denmark). All used reagents were of analytical grade unless otherwise specified.

2.2. Extraction of WEAX

Extraction of WEAX was performed according to Mansberger et al. (2014). Rye bran was heated at 130 °C for 150 min in an oven to inactivate present enzymes. Fifty gram bran was added to 500 mL deionized water with 0.01 mL α-amylase and stirred at 65 °C for 90 min. Afterwards solids were removed by centrifugation at 5000*g* for 10 min using an Avanti J-25 Beckman centrifuge (Beckman Coulter, Inc., NewYork, NY, USA). The pH value was lowered to 6.5 and 0.3 mL amyloglucosidase was added. Starch degradation was performed at 55 °C for 24 h. Then enzymes were inactivated by heat treatment for 30 min at 120 °C. The resulting solution was filtered (type 595, Whatman, Maidstone, England). To bind protein, 10% of a bentonite solution (0.2% mass) was added. After stirring at room temperature for 30 min, the solution was cleared again by centrifugation. Ethanol was added until the concentration of alcohol in the solution has reached 65% and stirred for 30 min to precipitate the WEAX. After centrifugation (5000*g*, 10 min) the pellet was washed once with ethanol (65%, 200 mL) and twice with 50 mL acetone. The washed material was air-dried overnight. The dry product was redissolved in deionized water (200 mL) and solids were removed by centrifugation (5000*g*, 10 min). Finally the supernatant was freeze-dried and grounded by a grinder (Model 6202, Xinzhen Instrument Technology Co. Ltd., Taiwan) to pass through a 100-mesh sieve.

2.3. Frozen dough preparation and steaming procedure

Chinese steamed bread was prepared according to GB/T 17320-1998 (China State Bureau of Technical Supervision & P.R. China, 1998). The basic recipe contained 450 g flour, 5 g yeast and 245 g water. Different WEAX contents (0%, 1% and 2% flour was replaced by WEAX) were added. 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 mixer was placed in a refrigerator (Isotemp Model, Thermo Fisher Scientific, Inc., Waltham, Mass) under 4 °C to minimize the activity of yeast. The dough was divided to 80 g pieces, molded, placed into snap lock polyethylene bags and followed by freezing at −18 °C. During the 60-day frozen storage, a batch of dough pieces were freeze-dried and the other batch of dough were thawed at 4 °C for 8 h every 15 days storage, fermented in a proof cabinet (Model JXFD 7, Dongfu Jiuheng Instrument Technology Co. Ltd., Beijing, China) at 30 ± 2 °C under 80 ± 5% relative humidity until the optimum height. The fermented dough was steamed in the in the tray above boiling water for 20 min. After steaming, the bread was cooled for exactly 2 h to room temperature, packed into plastic bags analyzed within 12 h.

2.4. Analysis of steamed bread qualities

The method for measuring steamed bread properties was adopted from GB/T 17320-1998 (China State Bureau of Technical Supervision, 1998) and GB/T 21118-2007 (China State Bureau of Technical Supervision & P. R. China, 2007) with slight modification. Bread was weighed and loaf volume was measured by rapeseed replacement. Firmness was measured by TA.XT2i (Stable Micro Systems, Ltd., Godalming, 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. The external (skin) and internal (crumb) color was measured by Chroma meter (Konica Minolta CR-100, Japan) equipped with D65 illuminant for values of L (lightness, white-black), a (color-opponent dimension, red-green) and b (color-opponent dimension, yellow-blue). The color difference, dE, was calculated as:

$$dE = \sqrt{(dL)^2 + (da)^2 + (db)^2}$$

where dL, da, and db were the differences for L, a, and b values between the sample and the reference (a white ceramic plate having L value of 93.4, a value of −1.8, and b value of 4.4).

For the image analysis, four slices (thickness 25 mm) were cut from the center of bread samples and images were captured using a flatbed HP Scanjet 5100C Photo Scanner (Hewlett-Packard, PaloAlto, CA, USA) supporting Desk Scan II software (Hewlett-Packard, USA). A single 50 × 30 mm field of view in the center of each slice was chosen for each image. Images were scanned full scale in 256 gray levels at 300 dots per inch (dpi) each comprising 470 columns by 470 rows of picture elements (pixels) and further processed using the image processing by Image J software v. 1.49 (NIH, Bethesda, USA).