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Study of the mechanism of improvement due to waxy wheat flour addition on the quality of frozen dough bread

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ABSTRACT

Waxy wheat flour (WWF) was substituted for 10% regular wheat flour (RWF) in frozen doughs and the physicochemical properties of starch and protein isolated from the frozen doughs stored for different time intervals (0, 1, 2, 4 and 8 weeks) were determined to establish the underlying reasons leading to the effects observed in WWF addition on frozen dough quality. Using Nuclear Magnetic Resonance (NMR), Differential Scanning Calorimeter (DSC) and X-ray Diffraction (XRD) among others, the gluten content, water molecular state, glutenin macropolymer content, damaged starch content, starch swelling power, gelatinization properties, starch crystallinity and bread specific volume were measured. Compared to RWF dough at the same frozen storage condition, 10% WWF addition decreased dry gluten and glutenin macropolymer contents and T_{23} proton density of frozen dough, but increased the wet gluten content, T_{21} and T_{22} proton density. 10% WWF addition also decreased damaged starch content, but increased starch swelling power, gelatinization temperature and enthalpy, crystallinity of starch and bread specific volume of frozen dough. Results in the present study showed that the improvement observed due to WWF addition in frozen dough bread quality might be attributed to its inhibition of redistribution of water molecules bound to proteins, increase in damaged starch content and decrease in starch swelling power.

1. Introduction

Frozen dough was developed in the 1950s, but is increasingly being produced worldwide especially in Europe and the United States in recent times. This has been attributed to the great advantages related to use of frozen dough such as time and energy saving for baking company, standardizing quality of final products and decreasing financial loss caused by staling (Matuda et al., 2005; Selomulyo and Zhou, 2007; Huang et al., 2008; Kim et al., 2008). However, during and after frozen storage, some undesirable changes in the dough and final products have been found. For instance, damage to the gluten network, death of yeast cells, and increase in dough fermentation time while the specific volume of the final products decrease (Inoue and Bushuk, 1992; Räsänen et al., 1998).

Waxy wheat flour (WWF), a new functional ingredient richer in amylopectin (99–100%) than regular wheat flour (RWF) (75%). WWF starch has been reported to have higher water absorption, form relatively clear pastes at low temperature and show less degree of syneresis than other wheat starches. WWF, as an ingredient in baked and sheeted wheat products has been used to improve shelf-life stability, processing quality and their palatability (Lee et al., 2001). The use of WWF as a cryoprotective of frozen dough has also been investigated. In this case, WWF dough exhibited less change of stickiness and extensibility after suffering frozen treatment, compared to RWF dough (Yi et al., 2009). The quality of frozen dough in which 10% RWF was substituted by WWF was the most stable comparing with other substitution level (Liu et al., 2012). However, there are limited studies on the underlying reasons on why frozen WWF dough stability was higher than RWF dough. Therefore, the aim of this study was to lay out the reason why addition of WWF caused an increase in frozen dough stability by investigating and correlating physiochemical properties of starch and protein and frozen dough bread-making properties.

Abbreviations: RWF, regular wheat flour; WWF, Waxy wheat flour; GMP, glutenin macropolymer; NMR, nuclear magnetic resonance; HMW/LMW, high molecular weight-glutenins/low molecular weight-glutenins.

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2. Materials and methods

2.1. Materials

The high-gluten flour and waxy wheat flour (WWF) were purchased from Eastocean Oils and Grains Industries (ADM joint venture, Zhangjiagang, China) and Jiangsu Chulong Flour Mills Co. Ltd., respectively. Moisture, ash, protein, lipids, starch, damaged starch, gluten (dry and wet) content were 12.8%, 0.58%, 13.5%, 1.75%, 69.42%, 6.60%, 11.38%, 34.68% (14% mb) for high gluten flour and 13.8%, 0.56%, 10.5%, 1.37%, 75.49%, 6.28%, 9.90%, 29.89% (14% mb) for WWF, determined by AACC Approved Methods 44-15A, 08-01, 46-12, 38–10.01 (AACC International, 2010), and Chinese Approved Methods GB/T 5009.9–2008, GB/T 9826-2008, GB/T 5506.1–2008 and GB/T 5506.3–2008 (SAC, 2008), respectively. Instant dry yeast was purchased from Panyu Meishan Mauri Yeast Co. Ltd. in Guangzhou, China.

2.2. Frozen dough preparation

Flour with 0% and 10% WWF and water at a ratio of 100:60 and 100:61.5 were mixed for 2.5 min at low speed and for 6.5 min at high speed in a Bud mixer (Shanghai Bud Food Co., Shanghai, China) until the gluten was optimally developed. After mixing, the dough was divided, molded and wrapped using a polyethylene sheet. The wrapped dough was frozen at −40 °C for 2 h until the center temperature of dough reached −18 °C, then the dough was transferred to an ice box (Qingdao Haier Co., Ltd., Qingdao, China) at −18 °C and stored for 0, 1, 4 and 8 weeks.

2.3. Gluten protein content determination

Dry and wet gluten proteins content were determined according to Chinese Approved Methods GB/T 5506.1–2008 and GB/T 5506.3–2008 (SAC, 2008). 10 g flour was mixed with 5 ml water in an enameled dish to make a dough without losing any flour or dough, after the dough was rested for 20 min, appropriate amount of water (15–20 °C) was added and the dough was kneaded by hand to remove the starch, bran and soluble constituents. Then the dough in water were sieved by using a fine sieve to remove the water and all gluten fragments were collected to make a dough. This process was done for 3–4 times until the water out of the dough was transparent. The gluten dough was squeezed to remove the water until the gluten dough became stick. The gluten dough was weighed to get the weight of wet gluten. The wet gluten was dried in 105 °C oven until a constant weight which was corrected to 14% water content to get the weight of dry gluten.

Wet gluten content = the weight of wet gluten (g)/the weight of flour (g) ×100

Dry gluten content = the weight of dry gluten (g)/the weight of flour (g) ×100

2.4. Water molecular state measurement

The water molecular state was determined using a 0.3 T 1HYOMINGMR2 IMAGING NMR spectrometer (Ningbo Jianxin Mechanical Co. Ltd. Ningbo, China) attached to a radioloop with 15.6 cm inside diameter. Frozen doughs were thawed at room temperature (25 °C) and 30 g dough was put into a plastic tube (25 mm O.D. × 50 mm length) was scanned in the center of the radioloop. Spin-spin relaxation times (T_2) were measured by Carr-Purcell-Meiboom-Gill (CPMG) pulse sequence. The CPMG data was fitted using T_2-fitfirm software.

2.5. Freeze-dried dough powder preparation

Frozen doughs were transferred to an ice box (Beijing Tiandijingyi Science and Technology Co. Ltd., Beijing, China) at −80 °C and frozen deeply for at least 24 h. The dough was then freeze-dried for 72 h in a freeze-drier (Ningbo Xinzhi Biotechnology Co., Ltd). The dried dough was milled in a mortar. The powder was sifted with 100 mesh sieve and the screen underflow was kept to be tested.

2.6. Glutenin macropolymer content determination

Glutenin macropolymer content was determined according to Weegels's method with little modification based on ultrasonication (Weegels et al., 1996; Zhang et al., 2010). Firstly, the standard curve of casein was made. Then the absorbance of samples was measured. 100 mg freeze-dried dough powder and 1 mL 50% isopropyl alcohol were put into a 1.5 mL centrifuge tube and centrifuged at 10,000 rpm for 15 min, the supernatant was discarded. This procedure was repeated three times. The precipitate was transferred into a 15 mL test tube with 10 mL deionized water. The solution was crushed for 5 min by using ultrasonic processor (JY98-IIIN, Ningbo Xinzhi Biotechnology Co. Ltd., Ningbo, China) to make a uniform emulsion. The emulsion was then centrifuged at 4000 rpm for 4 min, 1 mL supernatant and 4 mL allophanamide reagent was put into a 5 mL centrifuge tube which was shaken to make the mixture uniform and rested at room temperature for 30 min. The absorbance of the mixture at a wavelength of 562 nm was measured using a spectrophotometer (752, Shanghai Spectrum Instruments Co., Ltd, Shanghai, China). The protein content was calculated from the function of standard curve of casein based on the absorbance value of samples.

2.7. Damaged starch content measurement

The content of damaged starch of freeze-dried dough powder was determined according to AACC method 76–30.02 (AACC International, 2010).

2.8. Starch isolation and preparation

Starch was isolated from the dough using the manual washing method according to Zhang et al. (2014). The dough was washed with distilled water by hand to obtain a starch suspension which was centrifuged at 2000 g for 15 min, the supernatant was discarded. The starch precipitate obtained was freeze-dried, ground using mortar and pestle, and kept in plastic bags.

2.9. Swelling power and solubility of starch

0.32 g freeze-dried dough powder was put into a 50 mL weighed centrifuge tube with 5 mL 0.1 mol/L $AgNO_3$ solution, followed by shaking and heating at 70 °C for 10 min. The centrifuge tube was then placed in a boiling water bath for 10 min, cooled in ice water for 5 min and centrifuged at 1800 rpm for 4 min. The supernatant was transferred into a weighed aluminum box; the centrifuge tube with precipitate was tilted 45° for 10 min to pour out the residual supernatant completely. The aluminum box with supernatant and the centrifuge tube with the precipitate were oven dried at 60 °C (Sasaki and Matsuki, 1998). The swelling power and solubility of starch was calculated according to the following function: