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Effect of inulin with different degree of polymerization on plain wheat dough rheology and the quality of steamed bread

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ABSTRACT

The aim of this study was to evaluate the effect of different polymerization degree of inulin on plain wheat dough rheology and quality of steamed bread. It was found the water absorption of dough decreased with the increasing of short-chain (FS) and natural inulin (FI) and increased with the increasing of long-chain inulin (FXL) higher than 7.5%. Three kinds of inulin all increased the development time, stability and farinograph quality number and decreased softening degree of the dough. When proof time was less than 90min, the extensibility increased with the substitution of 5% of FS, 5% of FI and 2.5% of FXL. The resistance to extension, ratio number of resistance to extensibility and energy all increased with the increasing of FS and FI as well as the time. While the energy increased with FXL substation at 45min and dropped thereafter, regardless of the concentration. The addition of inulin all enhanced the brightness, specific volume and hardness of steamed bread and decreased the water content, vaporization enthalpy, springiness, recovery, and cohesiveness. During the storage, inulin reduced the change rates of relative hardness, recovery, and cohesiveness and increased the change rate of relative enthalpy, which restrained the staling rate of steamed bread.

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1. Introduction

Functional foods today play a more important role in food industry with the increase of consumer demand for nutrition and health benefits. In particular, the products enriched with dietary fiber have been considered an appealing subject to people, since it can reduce the risk of cardiovascular disease, intestinal disease and obesity (Brownlee, 2011). Inulin, as a soluble dietary fiber is a linear polysaccharide, which constituted by fructose molecules linked by $\beta\,(2 \rightarrow 1)$ bonds, with a terminal glucose unit linked by a $(1 \rightarrow 2)$ bond. According to the difference of degree of polymerization (DP), inulin can be divided into short-chain of inulin ($DP \leq 10$), natural inulin (DP 2-60) and long-chain inulin ($DP \geq 23$) (Chi et al., 2011). In earlier studies, inulin was mainly used as fat substitution, filler and structure formation (Pawel, 2010; Tárrega et al., 2011). Compared with dietary fibers from the cereals, legumes and vegetables, inulin has more outstanding physiological functions and processing performance (Kip et al., 2006). Various researches have confirmed that it can selectively promote the growth of probiotics, enhance the health of host, reduce blood glucose concentration, maintain the balance of lipid metabolism, improve the bioavailability of mineral element and strengthen organism immunity (Bosscher et al., 2006; Kaur and Gupta, 2002).

In recent years, there has been an increasing amount of researches on the applications of inulin in flour products. However, such researches remain narrow in focus studying only with the influence of inulin replacement or addition on rheological characteristics of high protein flour (Hager et al., 2011; Peressini and Sensidoni, 2009; Salinas et al., 2012) and gluten-free flour (Juszczak et al., 2012; Ziobro et al., 2013) as well as the quality of bread (Bojnanska et al., 2015; Filipović et al., 2015). There is a relatively small literature which is concerned with the effect of different degree of polymerization of inulin on plain flour and Chinese steamed bread. Chen et al. (2014) studied the effect of inulin addition on rheological properties of plain flour dough and noodle quality, which revealed that inulin addition contributed to reducing the water absorption and degree of softening of dough and the TPA parameters had significant change when the addition

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of inulin higher than 7.5%, while the DP of inulin did not mentioned. A similar result was observed by Luo et al. (2015), who reported that the substitution of shot-chain inulin enhanced the extensibility and stability of plain wheat dough. Liu et al. (2016a, b) pointed that the quality of Chinese steamed breads with lower than or equal to 5% inulin addition also were significant improved. But there is no report which is available to the influence of natural inulin and long-chain inulin on plain dough and steamed bread.

The objectives of this study was to investigate the effect of inulin with varying DP on the rheological properties of plain wheat dough, as well as Chinese steamed bread quality characteristics. These experimental results could be used to evaluate the feasibility of inulin as dietary fiber supplements in Chinese steamed bread.

2. Materials and methods

2.1. Materials

Plain wheat flour of 10.8% moisture, 0.51% ash, and 9.64% protein (Lvshuiyuan China), sodium chloride (Weiqun, China) and instant dry yeast (Angle brand, China) in this experiment were purchased from a local market. In addition, dried three kinds of inulin were used: Fibruline® S30 (FS, average DP ≤ 10, inulin content≥90%), Fibruline® Instant (FI, DP2~60, inulin content>86%) and Fibruline® XL (FXL, averageDP≥23, inulin content≥94.5%) (Cosucra, Belgium).

2.2. Preparation of wheat flour-inulin blends

Wheat flour was partially substituted by three kinds of inulin to prepare composite blends. Inulin levels used were 0, 2.5, 5, 7.5 and 10% (g inulin/100 g flour). The flour and inulin were mixed together 20 min to ensure evenly blending.

2.3. Farinograph and extensograph tests

The properties of the dough during development were tested by an S-300N farinograph (Brabender, Germany) according to the standard method (54-21). The water absorption (WA), dough development time (DT), stability time (ST), softening degree (SD) and farinograph quality number (FQN) of flour-inulin blends were determined.

Extension measurements were conducted in accordance with the standard produce using extensograph-E (Brabender, Germany). Dough prepared using the Farinograph-E were divided into two parts of 150 g each and retained for 45–135 min for proving. The dough extensibility (E), resistance to extension (R), ratio number of resistance to extensibility (R/E) and extension energy (Area) were obtained.

Measurements of the above farinograph and extensograph were carried out in duplicate.

2.4. Preparation of steamed bread

The control steamed bread formula contained 300 g wheat flour, 3 g dry yeast and 75% distilled water on the base of farinograph water absorption test. The steamed bread enriched with inulin was prepared according to the wheat flour partially substitution with the best level concluded by the farinograph and extensograph test. The yeast and inulin were individually dissolved in distilled water at 35 °C before they were mixed with wheat flour in a kneader (HM740, Hanshang Co., China) for 15min. After that, the dough was evenly divided into 4 pieces and placed in a fermentation room (FJ-12A, Yigao Co., China) at temperature 35 °C and humidity 83% for 40min. Then, the dough was again molded and continued fermentation for 20min followed by steaming for 10min using the boiling water. The steamed bread was cooled at room temperature for 1 h before testing.

2.5. Color measurements

The color of steamed bread crumb and crust was performed by a Minolta CR-400 colorimeter (X-rite Co., USA), which was calibrated before measure by the white and black standard tiles. The indices determined were L*(0: black, 100: white), a*(-a*: greenness; +a*: redness) and b*(-b*: blueness; +b*: yellowness). The measurements of every treatment were performed in three replicates.

2.6. Water content measurements

Moisture content of steamed bread crumb was determined by air oven method. The oven temperature was 105 ± 3 °C (44-15A). All the measurements were conducted in triplicate.

2.7. Specific volume measurements

The steamed bread after 1 h of cooling was weighed and the volume was determined by the millet replacement method, each group was performed in triplicate.

2.8. Differential scanning calorimeter (DSC) measurements

Thermal properties of steamed bread were performed using a DSC-1 (Mettler-Toledo, Switzerland) equipped with a nitrogen cooling system and an operation software for determination. Approximately 10 mg of the steamed bread sample was weighed in aluminum pan with an empty aluminum pan as the reference. The measurement process was as following: Sample was equilibrated at 25 °C for 5 min and then scanned from 25 °C to 190 °C at a heating rate of 10 °C/min. The water vaporization enthalpy was integrated and calculated.

2.9. Textural measurements

Texture property of steamed bread was measured after the storage of 1, 24, 48, and 72 h. The center crumb sample ($2 \times 2 \times 2$ cm^3) was removed by cutting and measured using a texture analyzer (Instron Universal 5544, Instron Co., USA) equipped with a 25 kg load cell and an aluminum cylindrical probe (P/36D). The test rate was 1 mm/s and the compress depth was 12 mm. The hardness, springiness, cohesiveness, and recovery character were calculated by the texture profile analysis curve. All the tests were conducted in triplicate.

2.10. Statistical analysis

The Origin software 8.5 was used in the data processing and graphics rendering. Statistical analyses were carried out using SPSS 19.0. All statistical analyses were done by analysis of variance (ANOVA). The significance level of $p < 0.05$ was used.

3. Results and discussion

3.1. Effect of inulin on dough rheology

3.1.1. Effect of inulin on farinograph parameters

Table 1 presents the summary statistics for the farinograph indices of dough with different DP of inulin. It is apparent that the water absorption (WA) of dough follows a linear decrease with the addition of FS ($WA = -2.23FS + 63.59$, $R^2 = 0.99$) or FI ($WA = -2.10FI + 63.28$, $R^2 = 0.96$). When 10% of wheat flour was

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