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Improvement of hydrocolloid characteristics added to angel food cake by modifying the thermal and physical properties of frozen batter

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A B S T R A C T

The effects of frozen storage conditions and hydrocolloids (carboxymethyl cellulose (CMC), locust bean gum (LBG) and xanthan gum (XG)) on angel food cake were investigated in terms of cake batter properties (viscosity, specific gravity, bubble size and uniformity and melting enthalpy of ice (ΔHm) and the characteristics of cake (specific volume and texture). Results showed that frozen storage caused a significant decrease in viscosity, a significant increase in ΔHm, specific gravity, bubble size and bubble non-uniformity, which resulted in the production of a denser and harder cake. Freeze–thaw cycle induced a more significant change than frozen storage for all above parameters of batter and cake. The addition of hydrocolloids retarded the change of viscosity, ΔHm, specific gravity, bubble size and bubble non-uniformity with frozen storage and freeze–thaw process, resulting in the improvement of the specific volume and textural properties of angel food cake. The biggest specific volume and smallest hardness belonged to cake containing 1% CMC in 4 weeks frozen storage or in 3 freeze–thaw cycles.

1. Introduction

Cake quality is usually determined by factors, such as batter viscosity, specific gravity and bubble distribution (Berry, Yang, & Foegeding, 2009; Mizukoshi, 1983a, 1983b; Mizukoshi, Maeda, & Amano, 1980; Pateras, Howells, & Rosenthal, 1994; Pernell, Luck, Foegeding, & Daubert, 2002; Yang & Foegeding, 2010). The amount and distribution (size and uniformity) of bubbles resulted from cake batter beating can be determined by batter viscosity and are used as the decisive factor for batter specific gravity and cake quality (specific volume and texture) (Handleman, Conn, & Lyons, 1961; Kim & Setser, 1992; Kim & Walker, 1992; Lee, Inglett, & Carriere, 2004).

Frozen dough is becoming popular because of not only its time saving, but also its contribution to the production of fresh baked foods (Kim, Huang, Du, Pan, & Chung, 2008; Matuda, Parra, Lugao, & Tadini, 2005; Selomulyo & Zhou, 2007). However, freezing and frozen storage causes ice formation and growth that result in the change of rheological and thermal properties of dough leading to the deterioration of baked foods' quality, such as smaller specific volume and harder crumb (Berglund, Shelton, & Freeman, 1991; Bhattacharya, Langstaff, & Berzonsky, 2003; Inoue & Bushuk, 1992; Leray, Oliete, & Mezaize, 2010; Mezaize, Chevallier, & Le-Bail, 2010).

Hydrocolloids can be used to control both the rheology and texture of aqueous systems through stabilization of emulsions, suspensions and foams (Selomulyo & Zhou, 2007). They could also provide stability for frozen products during freeze–thaw cycles and help to minimize the negative effects of freezing and frozen storage on starch-based products (Ferrero, Martino, & Zaritzky, 1993; Liehr & Kulicke, 1996). This is because hydrocolloids compete for water with polymers like protein and starch in dough, thereby decreasing water activity and control moisture migration in frozen dough (Schiraldi, Piazza, & Riva, 1996). The overall effects of hydrocolloids on dough and the subsequent bread quality depend on the nature, origin and particle size of the principal components, dosage of the hydrocolloids incorporated into dough, as well as the formulation, processing condition and other ingredients (Selomulyo & Zhou, 2007). Some investigators mentioned that gums such as carboxymethyl cellulose, carrageenan, xanthan gum, and locust bean gum may be used to alleviate the problems associated with frozen dough (Collar, Andreu, Martinez & Armero, 1999; Rosell, Rojas, & Benedito de Barber, 2001; Ward & Andon, 1993).

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Hydrocolloids were considered as an effective ingredient for improving quality of frozen dough products (Kobbs, 1997; Matuda et al., 2005; Matuda et al., 2006; Ribotta, León, & Añón, 2001; Sharadanant & Khan, 2003a, 2003b). Previous investigators suggested that the high water retention capacity of hydrocolloids inhibited ice formation and growth (Sharadanant & Khan, 2003a) and conferred stability to the frozen products (Ferrero et al., 1993; Lee, Baek, Cha, Park, & Lim, 2002; Liehr & Kulicke, 1996). It also decreases water activity due to the competition for water by the hydrocolloids with the bread polymers like protein and starch (Schiraldi et al., 1996). Ward and Andon (1993) found that gums such as carboxymethyl cellulose, carrageenan, gum arabic and locust bean gum could be used to alleviate the problems associated with frozen dough. Carboxymethyl cellulose (CMC), locust bean gum (LBG) and xanthan gum (XG) were the most widely used to improve qualities of frozen dough-making products (Matuda, Chevallier, Pessoa Filho, LeBail, & Tadini, 2008; Sharadanant & Khan, 2003a, 2003b; Ward & Andon, 1993).

The objective of this study was to investigate the effect of different hydrocolloids (CMC, LBG and XG) and frozen treatments (frozen storage time and freeze–thaw cycles) on the physical, thermal and cake-making properties of angel food cake batter.

2. Materials and methods

2.1. Materials

Soft wheat flour was purchased from Nanshun milling company in Jiangsu, China. Moisture, crude protein, crude fat and ash content in flour were 13.4%, 9.0%, 1.5% and 0.80% analyzed according to methods 44-15A, 46-13, 30-25 and 08-01 (AACCI 2000) method. CMC, LBG and XG were donated by Danisco (Kunshan) Co., Ltd., China. Soft sugar, salt, and eggs were purchased from local markets in Wuxi, China.

2.2. Preparation of angel food cake

The formulation of angel food cake includes 100 parts wheat flour, 308 parts egg white, 130 parts soft sugar, 2.5 parts salt and 1.5 parts tartar powder. All hydrocolloids (CMC, LBG and XG) were added at 1% (flour basis).

Egg whites, tartar powder and salts were whipped together in a standard kitchen mixer at middle speed until it became foamy. Then, soft sugar was added in three lots while whipping continued at high speed until soft peaks were formed. 50% wheat flour was sifted and gently folded just until flour disappeared, and then the other 50% wheat flour was repeatedly folded at a time. After mixing, the batter was weighed to 30 g each pan (fresh batter or batter frozen stored for 0 week) and baked for 20 min in the oven at 160 °C, top and bottom temperatures.

2.3. Freezing and thawing of batter

30 g batter in cup was covered by wrap film and frozen in a freezer at −35 °C for 2 h until the center temperature reached −18 °C, some cups of batter were stored at −18 °C for 1, 2 and 4 weeks, respectively. Others were subjected to 1 (1 week frozen storage and thawed), 2 (1 week frozen storage, thawed and 1 week frozen storage, thawed) and 3 (1 week frozen storage, thawed, 1 week frozen storage, thawed and 2 weeks frozen storage, thawed) freeze–thaw cycles, respectively. After frozen storage, batters were placed in a refrigerator at 10 °C for 6 h, which helped to thaw batter more homogeneously and completely.

2.4. Measurement of thermal properties

A batter sample (5–10 mg) was placed in an aluminum differential scanning calorimetry pan (Alod-Al) and frozen stored as described in Section 2.3. Before DSC experiment started, samples were immediately transferred from the freezer to the instrument in order to avoid water condensation on the surface of the pan and ice melting.

The thermal properties of batter systems were characterized using a differential scanning calorimeter (DSC, Pyris 1, Perkin–Elmer, Waltham, USA), previously calibrated with indium and sapphire. A sealed, empty aluminum pan was used as reference. Each sample was cooled to −30 °C at a rate of 5 °C/min, held for 5 min at −30 °C, and heated at a rate of 5 °C/min to +10 °C. The value of thermal property, namely melting enthalpy of ice (ΔHm) of batters was obtained directly from the thermal analysis software Pyris 1.

2.5. Determination of physical properties of batter

Specific gravity of angel food cake batter at room temperature (25 ± 2 °C) was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water.

The viscosity of batter was determined using viscometer (DV-II+ Pro, Brookfield Co., Germany). Spindle SC4-29 was used to mix batter at 20 rpm at room temperature (25 ± 2 °C) after 15 s resting.

2.6. Observation of bubbles distribution in batter

Microscopy with digital camera (Motic, Motic China Group Co., Ltd, China) was used to determine bubbles distribution in batters. Fresh or frozen stored angel food cake batter was spread on a slide and covered with a cover glass. The bubbles distribution in batter was observed with a magnification of ×10 on the viewing screen (Jyotsna, Sai Manohar, Indrani, & Venkateswara Rao, 2007). Bubbles distribution was evaluated using software Image J by the method of Li, et al. (2011). Pore area as a fraction of total area (AF), and the number of pores per square centimeter (cell density [CD]) were analyzed.

2.7. Evaluation of cake qualities

Each baked cake was allowed to cool to room temperature (rest for ≈1 h after baking) before volume measurement. Cake volume was measured using the sesame displacement method. The cake was placed in a container of known volume, which was topped off with sesame. Then the cake was removed and the volume of seeds was recorded. Cake volume was calculated as the difference between the total container volume and the volume of seeds. The volume divided by weight was the specific volume of angel food cake.

Hardness of cake crumb was evaluated by texture analyzer (TA-XT2i, Stable Micro System, Godalming, UK) at room temperature. The type of probe was P/50R, the pretest speed, the test speed and the post speed were all 1.0 mm/s. Cake was compressed to 50% of its original height and twice continuously. Hardness value (in the unit of g-force) was computed automatically by the data-processing software, obtained with the instrument, i.e. Texture Expert Version 1.20.

2.8. Experimental design and statistical analysis

Three measurements were taken for each experimental treatment from two different batches yielding in total six replicates for each treatment. The data obtained were presented as mean and standard deviation of the mean and were statistically treated by