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Effect of interesterified blend-based fast-frozen special fat on the physical properties and microstructure of frozen dough

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ABSTRACT

To better understand the effect of interesterified blend-based fast-frozen special fat (IBSF) on the quality of frozen dough, the physical properties and microstructure of frozen dough were investigated. The presence of IBSF in the frozen dough increased the gelatinization enthalpy (from 0.16 to 0.26 J/g) and decreased the degree of retrogradation (from 81.3% to 53.8%). The frozen dough added with IBSF also exhibited enhanced extensibility and greater flexibility. Data of DSC and Low-field NMR demonstrated that addition of IBSF significantly reduced the freezable water content and mobility of free water. SEM analysis showed that the starch granules were arranged in the gluten network of frozen dough. Compared with the corresponding physical blend-based special fat and commercial special fat, IBSF not only exhibited favorable influence on the quality of frozen dough, but didn't have trans-fatty acid. These results suggest that IBSF is promising in the preparation of prefrozen fast food.

1. Introduction

Recently, with the development of society and quick pace of life, the consumption of prefrozen fast food is increasing due to its convenient characteristic. Particularly, in China, the prefrozen fast food has developed very rapidly as a sunrise industry, especially some traditional Chinese prepared food, such as sweet dumpling ball (rice ball) and dumpling and their yields were exceeded 15 million tons annually (Li & Guo, 2010). The traditional Chinese prepared food, e.g. dumpling, consists of two portions (the dumpling wrapper and the fillings). The flour and water are firstly mixed and kneaded to supply the mechanical energy necessary to form the viscoelastic dough without fermentation. Then the non-fermented dough is formed into dumpling wrapper with the desired shape. At the same time, the fillings are prepared by different formulation. Finally, the dumpling product is achieved by sealing the filling into the dumpling wrapper completely. Nowadays, the prepared dough is developed as a separate unit process in the industry; especially the frozen dough is widely employed by both food factories and consumers. In application, both consumers and factories expect that the foods processed with frozen dough have satisfactory quality and sensory characteristics compared to those with fresh dough. Although the industrial-scale frozen dough has developed rapidly, there are still some problems occurring in its preparation, storage, and transportation. The excessive formation of the gluten network during dough preparation and the migration of water and the growth of ice crystals during freezing could result in the deterioration of the frozen dough (Baierschenk, Handschin, & Condepetit, 2005; Yi, Kerr, & Johnson, 2009), which in turn induce the collapse, cracking and coarse texture of the product based on frozen dough preparation.

Some efforts have been made over the years to improve the quality of frozen dough, including adopting various modified starches (Ferng, Liou, Yeh, & Chen, 2016; Mi, Liang, Lu, Tan, & Cui, 2014), adding additives such as thermostable ice structuring protein (Jia et al., 2012), monoglyceride (Goldstein & Seetharaman, 2011), using plastic fat (Jacob & Leelavathi, 2007), as well as controlling freezing conditions (Simmons, Smith, & Vodovotz, 2012). Among them, the addition of plastic fat into the fermented frozen dough has been shown as a practical way to improve the product quality since the fat can impart pleasing flavor, glossy appearance and desirable texture to these cereal-based products (Lee, Kim, & Inglett, 2005; Lim et al., 2017). Ma et al found that the addition of special fat with slip melting point (SMP) 45 °C, solid fat content 8.4–28.2 at 25–40 °C, decreased the cracking rate and produced shiny surface and good taste during the dumpling ball preparation (Wang et al., 2010). In our previous study, the base oil of the fast-frozen special fat with SMP 45 °C was prepared by lipozyme TL IM-catalyzed interesterification of palm stearin and soybean oil. The prepared fast-frozen dumplings with the interesterified blend-based special fat in it exhibited better performance (Zhu et al., 2017).

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The present studies showed that addition of this interesterified blend-based fast-frozen special fat into the non-fermented dough could improve the quality of fast frozen dumpling (Wang et al., 2010; Zhu et al., 2017). However, to date, there are few studies concerning the effect of this special fat on the quality of the frozen dough. The systematic investigation of physical properties, moisture and microstructure of the frozen dough with special fat in it will help us to better understand the influence of special fat on the quality of frozen dough. In order to give a deep insight into the effect of the above-mentioned interesterified blend-based fast-frozen special fat (IBSF) on the physical properties of the frozen dough, in this ongoing work, the non-fermented frozen dough with or without special fat in it were prepared and their physical properties and microstructure of the resulting frozen dough were investigated. As the interesterified blend-based fast-frozen special fat with 45 °C SMP is beneficial for application as indicated in previous studies (Wang et al., 2010; Zhu et al., 2017), the series of IBSF with SMP ≤ 45 °C (41 °C, 42 °C, 43 °C, 44 °C, 45 °C) were prepared to evaluate their probabilities in application to these prefrozen fast food. The corresponding physical blend-based special fat (PBSF) and a commercial special fat (C-SF) were added into the frozen dough as the positive controls. The gelatinization and retrogradation of resulting frozen dough were firstly measured by differential scanning calorimetry (DSC). Then the texture regarding extensibility and texture profile analysis (TPA) were monitored through the texture analyzer and the rheological property was evaluated by using the rheometer. Subsequently, the water distribution and freezable water content were systematically detected by low-field NMR (LF-NMR) and DSC measurement. Finally, the microstructure of the frozen dough was further determined by scanning electron microscope (SEM). The results present in this study will provide us some useful information about the effect of IBSF on the properties of frozen dough, which helps to broaden the application of IBSF in the large scale preparation of traditional Chinese prefrozen fast food.

2. Materials and methods

2.1. Materials

Refined, bleached and deodorized palm stearin (PS, SMP 52.0 °C) was supplied by Shenzhen Jingyi Co. (Shenzhen, China), and soybean oil (SO) was purchased from a local grocery store. Lipozyme TL IM (from *Thermomyces lanuginosus*, a sn-1,3-specific immobilized lipase, 800 PLU/g) was purchased from Novozymes (Guangzhou, China), which was stored at 4 °C before use. The fine wheat flour (ash 0.4%, protein content 10.2%, moisture content 12.0%) was brought from Shenzhen Taidongyuan Industrial Co., Ltd. A commercial special fat (C-SF, a kind of shortening) was obtained from Kerry oil chemical industry (Tianjin) Co., Ltd. All other reagents and solvents were analytical grade and were purchased from Sinopharm Chemical Reagent Co. Ltd. (Shanghai, China).

2.2. Fast-frozen special fat preparation

The enzymatic interesterified blends were used as the base oil to prepare the series of interesterified blend-based fast-frozen special fat with SMP ≤ 45 °C (41 °C, 42 °C, 43 °C, 44 °C, 45 °C) and the resulting fats were named as the 41 °C-45 °C-interesterified blend-based fast-frozen special fat (41 °C-45 °C-IBSF), respectively. The enzymatic interesterification was carried out in a fluidized-bed reactor (column length 35 cm, internal diameter 1.2 cm) and 10 g immobilized lipase lipozyme TL IM was packed in the internal column. A peristaltic pump was used to feed the substrate mixture with the mass ratio (6:4, PS:SO) and control its flow rate. The reaction temperature was 60 °C. Then the interesterified blend was used as the base oil to prepare the IBSF. The specific steps of making fast-frozen special fat were as follows. The solution containing 84 g base oil, 15 g water and 1 g emulsifier (Span-60:trimethylene glycol ester:soybean lecithin 1:1:8, wt%) was fully mixed at 60 °C and 2000 rpm for 20 min. The resulting mixture was kept at 40 °C for 10 min. After that, it was put into a refrigerated bath (−10 °C) and mixed at 300 rpm for 2 min, and then kept at 25 °C for 48 h. The IBSF were presented in Table S1†. The corresponding physical blend (PS:SO 6:4, wt%) was also used as the base oil to prepare the physical blend-based special fat (PBSF) following the steps mentioned above.

In addition, ATR-FTIR was used to determine whether there exist trans-fatty acid in the special fats used in this study (Sherazi et al., 2009). The infrared spectra of the special fats were collected using TensorII FTIR spectrometer (Bruker, Germany). A total of 32 scans were collected in the range 4000–400 cm^{-1} at a resolution of 4 cm^{-1}. Specific region of peak at 966 cm^{-1} has been traditionally compromised in the accuracy of determining trans-fatty acid by FTIR (Mossoba, Srigley & Kramer, 2015; Sherazi et al., 2009).

2.3. Frozen dough preparation

The dough-making raw materials, including flour 100 g, water 60 g, fast-frozen special fat 4 g, were weighed respectively. All of the dough ingredients were place in a laboratory dough blender and mixed for 10 min to obtain optimal dough development according to the method of Peng et al with some modification (Peng, Li, Ding & Yang, 2017). As soon as the dough was formed, it was wrapped with plastic membrane with round shape and frozen at −30 °C for 72 h. Then the frozen dough added with 41 °C-45 °C-IBSF were prepared, and the frozen dough added with PBSF and C-SF, respectively, were also prepared as the positive controls. The frozen dough without addition of fat was used as the blank.

2.4. Extensibility analysis

The extensibility of frozen dough was performed using SMS TA.XTPlus texture analyser (Godalming, Surrey, UK) with adapter A/KIE according to the method with some modification (Simmons et al., 2012). The sample was thawed at 25 °C for 3 h before testing. A ball of dough (5 g) was pressed into five strips (3 cm × 0.5 cm × 0.5 cm) by two plates with the grooved base. Then the strip of dough was secured by clamps and a hook attachment pulled the strip with a crosshead speed of 150 mm/min until ruptured. Measurement parameter setting were: pre-test speed 2.0 mm/s, test speed 3.3 mm/s, post-test speed 10.0 mm/s, distance 75 mm. The maximum force and extension at maximum load (resistance to extension (g) and extensibility (mm)) were extracted for extensibility analysis.

2.5. Texture profile analysis (TPA)

The texture profile analysis (TPA) of frozen dough was investigated by simulating a double mastication using a SMS TA.XT plus texture analyzer (Godalming, Surrey, UK) with an adapter A/DSC. The sample was thawed at 25 °C for 3 h before testing. For the experiment, the pre-test speed, test speed, post-test speed were 2.5 mm/s, 0.8 mm/s, 0.8 mm/s, respectively, and 70% compression strain of the sample was adapted in this test. Finally four texture parameters (hardness, springiness, cohesiveness, and resilience) were recorded.

2.6. Dynamic rheological measurement

The frozen dough (3 g) after thawing was conducted to dynamic oscillatory measurement using a controlled strain rheometer (DISCOVERY, TA Instruments Ltd., Leatherhead, UK). Plate-plate geometry with 20 mm diameter and 2 mm gap was used for the measurement. In order to protect the structural integrity of the sample during the measurement process, the amplitude scanning was performed before the frequency scanning to determine the linear viscoelastic region of the