Journal of Food Engineering 223 (2018) 53–61

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Effect of temperature on the crystallization behavior and physical properties of fast-frozen special fat during storage

Ting-wei Zhu [a, 1], Qin Liu [a, 1], Hao-tian Weng [b], Bing Li [a, c], Xia Zhang [a, c], Min-hua Zong [a], Hong Wu [a, c, *]

[a] School of Food Science and Engineering, South China University of Technology, Guangzhou 510640, China
[b] Department of Applied Mathematics, Northwestern Polytechnical University, Xian 710129, China
[c] Guangdong Province Key Laboratory for Green Processing of Natural Products and Product Safety, Guangzhou 510640, China

ARTICLE INFO

Article history:
Received 8 July 2017
Received in revised form
30 November 2017
Accepted 6 December 2017
Available online 7 December 2017

Keywords:
Fast-frozen special fat
Enzymatic interesterification
Crystallization behavior
Physical property
Storage temperature

ABSTRACT

The crystallization behavior and physical properties of fast-frozen special fat during storage at various temperatures were investigated. For the interesterified blend-based fast-frozen special fat (IBSF), the predominant β' form steadily existed during storage at 4 °C but the β' form gradually transformed into the β form when stored at $\geq$ 20 °C. However, the β content of the physical blend-based fast-frozen special fat (PBSF) was close to 64% and didn't change obviously during storage. For both samples, the crystal size increased and the crystalline network became porous as the storage temperature increased. There was little change in the hardness and solid fat content (SFC) of IBSF and PBSF when stored at 4 °C, but increasing temperature reduced their values. The results of sensory evaluation indicated that IBSF stored at 4 °C for 8 weeks still maintained good quality when applied in the preparation of fast frozen sweet dumplings.

1. Introduction

Nowadays, with the quick pace of life, the consumption of traditional Chinese fast-frozen foods, such as sweet dumpling balls (rice balls) and dumplings, is increasing due to their convenient characteristics in China (Li and Guo, 2010; Ma et al., 2009). As one of plastic fats, the fast-frozen special fat is widely used in the preparation of these traditional Chinese fast-frozen foods and plays an important role in providing them with desirable textural properties (Giannou et al., 2003). Presently, the fast-frozen special fats applied in the production of fast frozen foods are all-purpose plastic fats, such as margarines and shortenings etc which are mostly prepared by using refined animal fat, hydrogenated vegetable oil, or the blends of them as base oil. Refined animal fats are rich in abundant saturated fatty acid and the melting points of which are also high. On the other hand, the granular crystals in the animal fat-formulated margarines and shortenings which may be in relation to the β polymorph transformation impair the consistency, plasticity and mouthfeel of fat products in the application (Meng et al., 2010, 2011). The trans-fatty acids would be inevitably generated in the hydrogenation of vegetable oils and the intake of which would increase the risk of cardiovascular diseases (Fernández et al., 2007; De et al., 2001).

Enzymatic interesterification is one of promising oil and fat modification technologies which can improve the quality of plastic fat (Lee et al., 2008; Pande and Akoh, 2013). Presently, most of studies focus on investigating the effect of enzymatic interesterification on the physicochemical properties of blends and the resulting fats with interesterified blends as base oil (Adhikari *et a.* 2009; Lee et al., 2008; Pande and Akoh, 2013). However, except for the manufacturing process, the storage process, including the variation of storage temperature and time, also has impacts on the quality of plastic fats (Zhang et al., 2005). Nogala-Kalucka et al. found that it was suitable for margarine to be stored at 4 °C, as the nutrition and stability of margarine stored at 4 °C were higher than that stored at 20 °C (Nogala-Kalucka and Gogolewski, 2000). The storage temperature and time also affect the solid fat content (SFC) of margarine and the margarine could maintain predominant β' crystal form at low temperature (5 °C) (Goli et al., 2009). However,

Abbreviations: IBSF, the interesterified blend-based fast-frozen special fat; PBSF, the physical blend-based fast-frozen special fat.

* Corresponding author. School of Food Science and Engineering, South China University of Technology, Guangzhou 510640, China.
E-mail address: bbhwu@scut.edu.cn (H. Wu).

[1] These authors have the same contribution.

https://doi.org/10.1016/j.jfoodeng.2017.12.002
0260-8774/

to date, there is little report about the quality changes of fast-frozen special fats during storage process.

In the previous studies, we prepared the base oil of the fast-frozen special fat by lipozyme TL IM-catalyzed interesterification of palm stearin (PS) and soybean oil (SO). The interesterified blends showed ideal crystal form (majority of β' crystal) and physical properties (SFC being 40%–5% at 10–45 °C) and the resulting fast-frozen special fats prepared with the enzymatic interesterified blends as base oil exhibited better performance in their application for fast-frozen food production than those of fast-frozen special fats prepared with physical blends as base oil (Zhao et al., 2016; Cui et al., 2014; Zhu et al., 2017). In order to understand the storage stability of fast-frozen special fats, the physical properties and crystallization behavior of the above interesterified blend-based fast-frozen special fat (IBSF) during storage at different temperature (4, 20 and 30 °C) for a period time were investigated in this study. Additionally, the physical properties and crystallization behavior of the physical blend-based fast-frozen special fat (PBSF) with the same ratio of PS and SO under the same storage conditions were also comparatively studied. The basic molecular structure about the fatty acid and triacylglycerol (TAG) composition of IBSF and PBSF were firstly measured by gas chromatograph (GC) and reversed-phase high-performance liquid chromatography (HPLC), respectively. Then, their relevant physical properties regarding hardness and SFC were monitored through the texture analyzer and a low-resolution pulse nuclear magnetic resonance spectrometer (pNMR). Subsequently, the crystal polymorphism and crystal microstructure of IBSF and PBSF were detected by X-ray diffraction (XRD) and polarized light microscopy (PLM), respectively. Finally, the fast-frozen special fats before and after storage was applied in the preparation of fast-frozen sweet dumpling balls and the sensory properties of which were further evaluated. The results achieved here will provide helpful information on how to maintain good quality of fast-frozen special fats during storage.

2. Materials and methods

2.1. Materials

Palm stearin (PS, slip melting point 52 °C) was supplied by Shenzhen Jingyi Co. (Shenzhen, China), and soybean oil (SO) was purchased from a local grocery store. Lipozyme TL IM (1,3-specific immobilized lipase, 1130 U/g) was purchased from Novozymes (China) Biotechnology Co., Ltd. (Guangzhou, China). The commercial fat was obtained from Kerry oil chemical industry (Tianjin) Co., Ltd. All other reagents and solvents were analytical or chromatographic grade and were purchased from Sinopharm Chemical Reagent Co. Ltd. (Shanghai, China).

2.2. Enzymatic interesterification

The enzymatic interesterification was carried out in a conical flask at 60 °C and 200 rpm for 5 h. The reaction mixture contained 70 g PS and 30 g SO (7:3, wt%), and 10 g immobilized lipase lipozyme TL IM.

2.3. Preparation of fast-frozen special fat

The physical blend (PS:SO 7:3, wt%) and enzymatic interesterified blend were used as the base oil to prepare the two fast-frozen special fats and the resulting fats were named as the physical blend-based fast-frozen special fat (PBSF) and the interesterified blend-based fast-frozen special fat (IBSF), respectively. 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.

2.4. Storage protocol

The fast-frozen special fats (PBSF and IBSF) were cut into 20 × 12 × 5 cm blocks in length, width and height, respectively, and then stored at 4 °C, 20 °C and 30 °C for 8 weeks, 8 weeks and 3 weeks, respectively. The stop of experiment after 3 weeks when stored at 30 °C was because oil exudation was occurred in the sample. Three parallel experiments were performed. Then the physicochemical properties of the sample and the textural properties were analyzed by gas chromatograph (GC), X-ray diffraction (XRD), polarized light microscopy (PLM), low-resolution pulse nuclear magnetic resonance (pNMR) and texture analyzer.

2.5. Fatty acid (FA) composition

Fatty acid methyl ester (FAME) was prepared according to AOCS Official Method Ce 2–66 (AOCS. 2004a) and subsequently analyzed on a GC-2010 gas chromatograph (GC) equipped with a flame ionization detector (Shimadzu, Tokyo, Japan) and a DB-Wax capillary column (length 30 m, internal diameter 0.25 mm, film thickness 0.25 μm, Agilent Inc., USA). The temperature of injector and detector were set at 260 °C and 280 °C, respectively, and injection volume was 1 μL. Nitrogen was used as the carrier gas at 1 mL/min. Split ratio was 1:100 (v/v). The column temperature was kept at 190 °C for 2 min, and then increased to 210 °C at 5 °C/min.

2.6. Triacylglycerol (TAG) composition analysis

The TAG of the samples (PBSF and IBSF) were analyzed by reversed-phase high-performance liquid chromatography (HPLC) equipped with an evaporative light scattering detector (ELSD) and a symmetry C18 column (5 μm, 4.6 × 150 mm). The sample (30 mg) was dissolved in 30 mL chloroform and then filtered with a 0.22 μm membrane filter before determination. The mobile phase was a binary solvent system of acetonitrile (solvent A) and 2-propanol/hexane (5:4, by volume) (solvent B) at a flow rate of 1.0 mL/min. The detector temperature was 70 °C. The injection volume was 3 μL. The individual TAG content was calculated as percentage of the peak area of individual TAG relative to the total peak area of the total TAGs in the sample.

2.7. Hardness analysis

The hardness of the samples (PBSF and IBSF) was determined by using a TA.XT-Plus texture analyzer (TA Instrument Inc., U.K.). A 45° conical probe was inserted into the sample to a penetration depth of 10 mm at 2 mm/s. The maximum recorded force (g) was defined as the hardness of the sample. The samples were prepared in triplicate for each analysis.

2.8. Solid fat content (SFC) determination

A low-resolution pulse nuclear magnetic resonance (pNMR) spectrometer (Bruker, Germany) was used to determine the SFC according to AOCS Official method Cd 16b-93 (AOCS. 2004b). The fat was completely melted at 80 °C for 30 min and then cooled at 0 °C for 60 min in a high precision dry bath. Then the sample was conditioned at each chosen measuring temperature for 30 min.