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Investigating the effect of deforming temperature on the oil-binding capacity of palm oil based shortening

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ABSTRACT

This study investigated the effect of deforming temperature on the oil binding capacity (OBC) of a palm oil-based shortening (melting point 40 °C). The shortening was treated with three different temperature conditions namely, Set A at 25 °C for 8 h, Set B at 40 °C for 8 h and Set C at 70 °C for 2 h. Stability analyzer (LUMiFuge, Germany) that applies centrifugal force with an in-built near infrared (NIR) detector was used to measure the amount of free oil released from the shortenings. Other characteristics such as crystal size, solid fat content (SFC), hardness and aerating ability were also studied. The stability analyzer successfully measured the OBC, with the highest in Set A (99%) followed by Set B (94%) and Set C (89%). The increase of deforming temperature resulted in the increase of crystal size that decreased the OBC, which consequently decreased the SFC, hardness and aerating ability of the shortening.

1. Introduction

Shelf-stable general-purpose shortenings are produced with a melting temperature between 37 °C and 44 °C for use in the tropical Southeast Asian countries. In these countries, such products are commonly transported by road using non-refrigerated vehicles. During day time transportation, the products are often exposed to elevated temperatures, which in extreme case may exceed 40 °C. Exposure to these high temperatures can lead to instability of the product as reflected by structural deformation due to partial melting of the product (Juriaanse and Heertje, 1988). Physical stability is a critical characteristic that determines the shortening's performance in end-products such as breads, biscuits, cakes, creams and pastries (Garcia-Macias et al., 2011; Gerstenberg Kirkeby, 2011; Pajin et al., 2011). Thermal exposure may cause deterioration of the products' performances, and in severe cases, the products may become unusable.

Shortenings are commonly processed by instantaneous superchilling methods whereby, the oil and fat blends are instantaneously cooled to form a homogenous, even and smooth product. This instantaneous crystallization enables the crystal networks to entrap liquid oil, and results in a homogenous solid product. The individual crystals bond together through forming a continuous crystal network of solid phase, called 'plastic fat' (Heertje, 1993; Litwinenko et al., 2002; Marangoni and Hartel, 2006; Narine and Marangoni, 1999d). The characteristics of plastic fat are determined by the shape, average size and size distribution of the crystals as well as the liquid–solid phase balance. The strength of the crystal network is influenced by the degree of crystal aggregation and solid bridge formation among the crystals (deMan et al., 1990).

The sensory attributes such as spreadability, mouthfeel and texture of the food containing a significant amount of fats, are dependent on the microstructural properties of the fat system (Campos et al., 2002; Narine, 2005). The texture of shortening is an important property that strongly influences the perceived quality of the food products (Brunello et al., 2003). The texture of shortenings, margarines and butters usually includes properties such as hardness, smoothness, graininess, brittleness, oiliness and stickiness. Fat-based products differ in textural properties due to variations in crystal strength. Crystal strength is determined by the size of the crystals, crystal size distribution and the strength of the crystal network (deMan et al., 1990).

The physical state of plastic fat is significantly influenced by thermal treatments during processing and storage. This study aims at investigating the effect of deforming temperature on the OBC of a palm oil-based shortening consisting of 90% palm oil and 10% palm stearin, which gives a melting point of 40 °C. The three temperatures selected were the normal storage temperature of 25 °C, extreme open vehicle transportation condition of 40 °C (tropical climate) and a total fat crystal melt temperature of 70 °C. This

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might occur if the cargo containers carrying shortening were accidentally placed near the ship's boiler during shipping.

Temperature is considered to be one of the main parameters that deteriorate the quality of shortening as it deforms the crystal structure, thus affecting the liquid–solid phase balance of the shortening. In this study, stability is defined as the oil-binding capacity, which is the ability of the liquid and solid phases within the fat blend to remain as a continuous and homogenous solid phase. Oil-binding capacity in turn is defined as the liquid portion (liquid entrapped within the crystal structure) that cannot be separated by centrifugal forces In this study Stability analyzer (LUMiFuge, Germany) that applies centrifugal force with an in-built near infrared (NIR) detector was used to measure the amount of free oil released from the shortenings. In this method, a stainless steel piston was used to penetrate into the sample and obtain an intact sample without damaging the preformed crystal structure. The sample is gently placed in the centrifugal cell and the OBC is directly measured. This is an easy, simple and a one-step method in compared to other methods (Jahaniaval et al., 2002; Omonov et al., 2010). Other characteristics such as crystal size, solid fat content (SFC), hardness and aerating ability of the shortening samples were also studied.

2. Materials and methods

2.1. Preparation of experimental shortening

This study focuses on effect of deforming temperature on the oil-binding capacity of palm oil based shortening. The prerequisite of palm based shortening for this evaluation was a totally palm oil-based shortening with a melting point of 40 °C. The experimental palm oil-based shortening blend was prepared and processed to acquire the fine, firm and homogenous texture of shortening.

The experimental palm oil-based shortening with a melting point of 40 °C was prepared by blending 90% palm oil and 10% palm stearin. (Palm oil of melting point was 36 °C and palm stearin melting point was 50 °C.) The crystallization or texturization process was carried out in a prefector pilot plant (Gerstenberg and Agger, Copenhagen, Denmark). The blend was placed in a feed tank and heated to 65 °C for an hour to ensure total melt. The blend was then maintained at 65 °C and processed through the first chilling unit (scraped surface heat exchanger: Unit A). The main function of this unit was to instantaneously cool the blend by reducing the temperature of the blend from 65 °C to 45 °C. The blend was further chilled by passing it through the second chilling unit to instantaneously reduce the temperature from 45 °C to 25 °C. The rotation speed of both the scraped surface heat exchanger shaft was set at 450 rpm. The blend was then homogenized by further processing it through a pin worker (Unit B), with the rotation speed of the shaft set at 150 rpm. This experimental shortening was collected in 500 g containers and stored at 25 °C. The slip melting point and fatty acid composition of the experimental shortening was determined.

2.1.1. Slip melting point (SMP)

Slip melting point (SMP) was determined by MPOB Test Method p4.2: 2004. Three capillary tubes were filled with a 10 mm high column of fat. The fat column was chilled by holding and rolling the ends of the tubes containing the samples pressed against a piece of ice until the column of oil solidifies. The tubes were placed in a test tube and held in a beaker of water equilibrated at 10 ± 1 °C in a thermostat water bath. The beaker was transferred to the water bath and held for 16 h at 10 ± 1 °C. The capillary tubes were then removed from the test tube and attached to a thermometer with a rubber band such as that the lower ends of the tube leveled with the bottom of the mercury bulb of the thermometer. Subsequently, the thermometer was suspended in a beaker containing 400 ml boiled distilled water such that the lower end of the thermometer was immersed in the water to a depth of 30 mm. The starting temperature of the bath was adjusted to 8–10 °C below the expected SMP of the sample. The water was agitated with a magnetic stirrer and heat was applied to increase the temperature at the rate of 1 °C/min, slowing down to 0.5 °C/min as the slip point was reached. The heating was continued until the fat column was raised. The temperature at which the fat column rose was reported as the SMP.

2.1.2. Fatty acid composition (FAC)

Fatty acid composition was determined as fatty acid methyl esters (FAME). The samples (0.05 g) were weighed and dissolved in 1 ml hexane. The mixture was then added with sodium methoxide solution (0.2 ml of $NaOCH_3$ (2 M) in anhydrous methanol) and then mixed for 1 min with a vortex mixer. After sedimentation of sodium glycerolate, 1 μm of clear supernatant was injected into Rtx 2330 fused silica capillary column (60 m × 0.25 mm × 0.25 μ) (Restex Corporation USA) and analyzed using a Burker Gas Chromatography system Model 430-GC (Burker Daltonics, CA, USA) equipped with a flame ionization detector (FID) and Galaxie Chromatography Data System. Injection and detection temperatures were set at 240 °C. The oven temperature was set at 190 °C. The column temperature was isothermal at 185 °C. The carrier gas was helium with flow rate of 1 ml/min. The peaks were identified by comparing retention times with FAME standards and quantified using peak area normalization method.

2.2. Thermal treatment

The experimental shortening that was produced in Section 2.1 was used in the following temperature treatments. The experiment was set up to study the effect of deforming temperature on the oil-binding capacity of palm oil-based shortening. The study focused on three significant temperatures of 25 °C, 40 °C and 70 °C. The selection of 25 °C was based on the common temperature set at refrigerated storage facilities and transportation vehicle by domestic shortening manufacturers in Malaysia. The selection of 40 °C was based on the typical midday temperature of non-refrigerated storage facilities and transportation vehicle in Malaysia. The experimental shortening evaluated in this study has a slip melting point of 40 °C, hence partial melting or softening of this shortening will occur when the shortening is stored at 40 °C. The effect of this deformation is of interest in this study. The selection of 70 °C was based on the temperature required to totally melt the experimental shortening (some triacylglycerols in palm based solids have melting points as high as 63 °C). Hence the texture the experimental shortening obtained when processed through prefector pilot plant will be completely destroyed as the fine crystals formed during texturization will be completely melted at 70 °C. This deformation temperature will also be able to provide comparison characteristics of fully texturized shortening and randomly recrystallized shortening.

Three sets of samples were prepared and labelled as Set A, Set B and Set C. Each Set contained triplicate sample of 500 g. These three sets were subjected to four steps of temperature conditions as shown in Table 1. Step 1 was the conditioning of the three sets at 25 °C for 24 h. Step 2 was the focus step of this study, where the variation of temperatures was applied. Set A was treated by placing at 25 °C for 8 h, Set B at 40 °C for 8 h and Set C at 70 °C for 2 h. Note: Set C was treated for a shorter period (2 h instead of 8 h), as to minimize oxidation and quality deterioration of the shortening due to exposure to the high temperature. In Step 3 all samples were tempered at 25 °C for 48 h. In Step 3 partially melted or