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Effect of the addition of palm stearin and storage temperatures on the thermal properties of glycerol monostearate-structured emulsions

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ABSTRACT

Monoglyceride (MG) structured oil-in-water emulsions have been developed as low fat shortening alternatives. In this work, the effect of the addition of palm stearin (PS) and storage at different temperatures on the thermal properties of glycerol monostearate (GMS)-structured emulsions were characterized. The melting profile and the dropping point of GMS-structured emulsions were investigated during five weeks of storage at 8 °C and 22 °C. Results showed that the addition of PS changed the melting profiles of GMS-structured emulsions that were stored under refrigeration temperatures, possibly by reducing phase separation between GMS and co-emulsifiers. Storage at refrigeration temperatures increased the stability of the α-gel phase while storing at room temperatures accelerated emulsion destabilization. Even though samples stored at refrigeration temperatures had lower dropping points, they were in the α-gel phase, making refrigeration temperatures the desirable storage condition to achieve maximal stability of MG-structured emulsions.

1. Introduction

The increasing market and consumer demand for healthy food products has forced the food industry to seek replacements for products that contain high amounts of saturated fats and *trans* fats. From a technological point of view, the use of saturated and hydrogenated fats has many advantages because they contribute to desirable structural, functional, and sensory properties of food products. The major challenge therefore, is finding and developing healthy alternatives that have similar or better sensory properties. Recent research has shown that non-triglyceride-structured-edible oils show strong potential for replacing hard-stock fats in food products (Co & Marangoni, 2012; Patel, 2015; Wang, Gravelle, Blake, & Marangoni, 2016; Zetzl & Marangoni, 2011, 2014).

Among processed food products that are high in *trans* fats and saturated fats are baked products, which usually contain high amounts of fat originating from shortening. In order to successfully replace shortenings, lower fat alternatives should mimic some key functionalities that traditional shortenings have in baked goods. Some of these properties include: i) they are able to reduce the formation of gluten network, ii) they are spreadable at room temperature so that they could be mixed with other ingredients in the dough, and iii) they are solid at the working temperature of the dough and have high level of stability at elevated baking temperatures (Blake & Marangoni, 2015; Ghotra, Dyal, & Narine, 2002; Litwinenko, Rojas, Gerschenson, & Marangoni, 2002).

A monoglyceride (MG) structured emulsion has been developed as a low fat shortening and it has been commercialized under the trade mark Coasun™ (Marangoni & Idziak, 2010; Marangoni et al., 2007). Such structured oil-in-water (o/w) emulsion is formed by creating a stable system that contains 10–70% (w/w) of liquid oil, 3–6% (w/w) of saturated MGs and co-emulsifiers with the rest being water. This emulsion has a structure where an oil droplet is surrounded by alternating MG-bilayers and water layers, through which a fat-like gel network is formed (Batte, Wright, Rush, Idziak, & Marangoni, 2007b; Marangoni et al., 2007). The unique architecture of the structured emulsion allows it to be formulated with different liquid oils and fat-soluble nutrients in order to be tailored into different physical properties for applications in a variety of baked products, such as bread, cookies, and laminated puff pastries (Blake & Marangoni, 2015; Calligaris, Manzocco, Valoppi, & Nicoli, 2013; Goldstein, Marangoni, & Seetharaman, 2012; Marangoni & Idziak, 2007).

The structural and mechanical properties of MG-structured emulsions have been characterized by our group (Batte, Wright, Rush, Idziak, & Marangoni, 2007a; Batte et al., 2007b; Goldstein et al., 2012; Wang & Marangoni, 2016). One difficulty in using this novel low-fat shortening is that the MG emulsifiers used to structure this system have polymorphic and mesomorphic properties and undergo a polymorphic transformation after storage for a certain period of time (Krog & Borup, 1973; Krog & Larsson, 1968; Larsson, Gabrielsson, & Lundberga, 1978). When preparing the emulsion, both the water phase (water, preservative, and hydrocolloids) and the oil phase (oil, MGs, and co-emulsifiers) are heated above the Krafft temperature (T_k) of the MGs (Batte et al., 2007b). Upon homogenization, the oil phase is added to the water phase, allowing the MG molecules to self assemble into an L_α liquid crystalline phase, and subsequently cooling below T_k leads to the formation of a hydrated lamellar L_β phase (also called the

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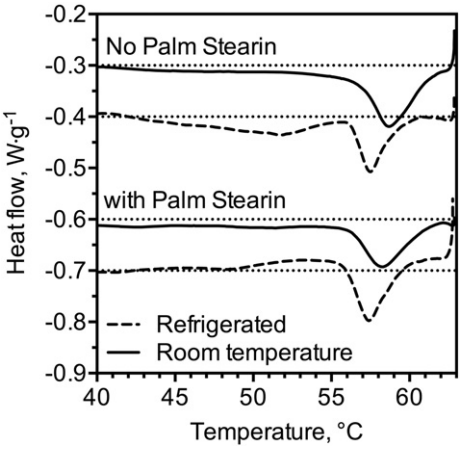

Fig. 1. DSC melting curves of MG-structured emulsions that contain 35% (w/w) of water with and without palm stearin (PS) stored at 22 °C and 8 °C for one week.

α-gel phase) (Krog & Larsson, 1968; Zetzl, Ollivon, & Marangoni, 2009). The α-gel phase is thermodynamically unstable and will transform into a more crystalline and less hydrated $L_{\beta'}$ phase (also called the coagel phase) accompanied by water syneresis, which results in the loss of the fat-like property and destabilization of the emulsion (Krog & Larsson, 1968).

The stability and rheological properties of this emulsion have been shown to be affected by numerous factors such as the chain length of MG molecules, types and concentration of co-emulsifiers, addition of waxes and hydrocolloids, changes in pH, and various cooling conditions (Batte et al., 2007a; Blake & Marangoni, 2015; Da Pieve, Calligaris, Co, Nicoli, & Marangoni, 2010; Goldstein et al., 2012; Wang & Marangoni, 2015b).

Recent research trends on this area have been focusing on improving the thermal stability and shelf life of MG-structured emulsions for better functionality and higher stability. This work, therefore aims to characterize the effect of oil concentration, addition of a hard stock fat, and storage temperature on thermal properties and stability of MG-structured emulsions.

2. Experimental

2.1. Sample preparation

The water phase and oil phase were weighed in separate beakers. The water phase contained distilled water, while the oil phase contained canola oil (Caldic, Mississauga, ON, Canada), glycerol monostearate (Alphadim 90 SBK, Caravan Ingredients, Lenexa, KS, USA), and stearic acid (Sigma-Aldrich Canada, Okaville, ON, Canada). All the emulsion samples were structured as 4.5% (w/w) MG and 0.22% (w/w) stearic acid with 60% (mole/mole) neutralized with NaOH solution. Two sets of emulsions were prepared in different oil to water ratios: 60:40, 65:35, and 70:30 (oil:water, w/w). Palm stearin (PS) was added at 10% (w/w) in the oil phase to one set of the emulsion samples.

The water phase and the oil phase were heated in a microwave oven. Sample temperatures were measured with a thermometer throughout the heating interval until the temperature reached 75 °C. The oil phase was added slowly to the water phase while homogenizing with a Kitchen Aid immersion blender (Whirlpool Corporation, St. Joseph, MI, USA) set at speed two. The oil addition times varied depending on the composition, where the 60:40 (w/w) oil:water was added in 25 s and the 70:30 (w/w) oil:water was added in 45 s.

Half of each sample was then passed through a Komax static mixer (Komax Systems Inc., Huntington Beach, CA, USA) with a fluid velocity of 60 mL per minute, while the other half was passed through a three-stage single pass rotor-stator homogenizer (Magic Lab, IKA, Staufe, Germany) set at rotational speed of 12,000 rpm. All the samples were stored at 22 °C and 8 °C for five weeks.

2.2. Differential scanning calorimetry (DSC)

The melting profiles of the samples were measured with a TA DSC analyzer (Q-1000 calorimeter, TA Instruments, New Castle, DE). Approximately 10 mg of sample was placed in hermetically sealed pans and heated from 35 °C to 65 °C, cooled from 65.00 °C to 35 °C, and then reheated to 65 °C at 5 °C per minute. Peak integrations were preformed with Universal Analysis 2000 (TA Instruments, New Castle, DE), where the enthalpy and the peak temperature of melting/crystallization were determined. Samples were measured in replicates.

2.3. Dropping point (DP)

Samples were inserted into a Mettler FP800 Dropping Point Cell (Mettler Toledo Canada, Mississauga, Canada) and heated from the initial temperature of 40.0 °C at 5.0 °C per minute to the dropping point temperature. The average dropping point of each sample was calculated from five measurements.

3. Results and discussion

The thermal properties of emulsions mixed with the rotator–stator and Komax mixer displayed the same melting profiles throughout the incubation period, therefore only results obtained from samples prepared with the rotator–stator are discussed in the following sections.

The melting curves of MG-structured emulsions that contain 35% (w/w) water with and without PS stored at 22 °C and 8 °C for one week are compared in Fig. 1. Samples with and without PS both showed a flat baseline and one melting peak at ~58 °C after storage at room temperature for one week. The emulsion stored at 8 °C without PS, on the other hand, showed a broad peak before the melting peak at ~57 °C, similar to the shoulder observed in the melting curve of

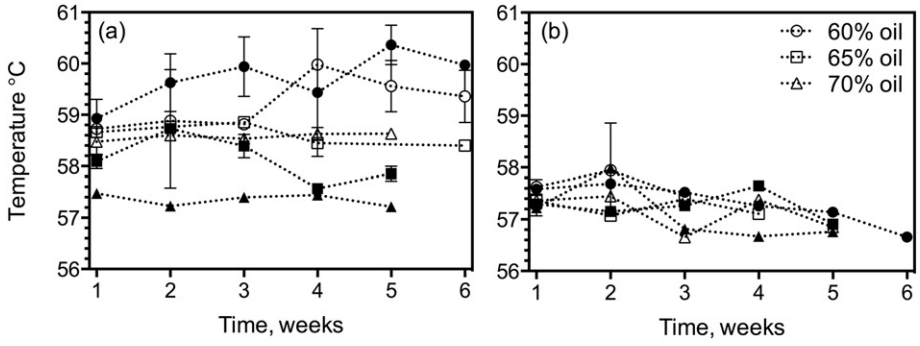

Fig. 2. Peak melting temperature of MG-structured emulsions stored at (a) 22 °C and (b) 8 °C. Empty symbol: without palm stearin; solid sample: with palm stearin.