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Applications and effects of monoglycerides on frozen dessert stability

L.Y. Lee[a,b,*], N.L. Chin[b], E.S. Christensen[a], C.H. Lim[a], Y.A. Yusof[b], R.A. Talib[b]

[a] Knowledge & Discovery Application Centre, Futura Ingredients, Lot 11, Section 5, Fasa 2B, Pulau Indah Industrial Park, Jalan Sg. Pinang 4/2, 42920, Pulau Indah, Selangor, Malaysia

[b] Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia

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ABSTRACT

The main variations in monoglycerides are its fatty acid composition and degree of unsaturation. This study aimed to evaluate monoglycerides of different degree of unsaturation on stability of ice creams, which is also known as frozen desserts because of vegetable fat usage. This was in view of the fact that saturated monoglycerides and its blend with polysorbate 80 had been used historically in ice creams formulations instead of unsaturated monoglycerides. Stability in terms of aeration performances were measured through quantification of fat globules size distribution, meltdown resistance and heat shock stability. The meltdown rate between the saturated and unsaturated monoglycerides was 0.17–0.26% per min and 0.12–0.19% per min respectively. Frozen desserts with meltdown rate below 0.2% per min was defined to have good meltdown resistance performance. Unsaturated monoglycerides performed better than saturated monoglycerides alone and saturated monoglycerides blended with polysorbate 80 in frozen dessert stability.

1. Introduction

Ice cream is both an emulsion and foam, comprised of four structures which are ice crystals, air bubbles, fat globules and aggregates, and the unfrozen serum phase (Clarke, 2005; Goff & Hartel, 2013). It may be termed frozen dessert if the fat level and source is outside the legislative definition. The structure of ice cream and frozen dessert develops progressively as the mix goes through the processing stages. The making of ice cream and frozen dessert starts from mix preparation which includes mixing, heat treatment and homogenization, follows by aging, freezing and finally hardening (Goff, 1997). The incorporation of air into ice cream and frozen dessert happens simultaneously during freezing in the ice cream freezer which is a scraped surface heat exchanger. As air is drawn into the mix in the form of large air bubbles, the shearing action in the ice cream freezer helps to divide them into tiny air bubbles and distribute them evenly within the ice cream and frozen dessert matrix (Clarke, 2005).

The efficiency of air incorporation and rate of it happening are highly influenced by the mix composition and processing parameters particularly aging duration and freezing conditions (Goff, Verespej, & Smith, 1999). Milk proteins in ice cream and frozen dessert formulations are sufficiently efficient in imparting emulsion stabilization through steric stabilization. However, a strong emulsion is undesirable for aeration, such as in ice cream and frozen dessert. Therefore, the protective protein layers on fat globule surface membranes needs to be weaken in order to reduce the steric stabilization effect. This could be achieved with the use of low molecular weight emulsifiers such as monoglycerides to induce protein displacement from fat globules surface membranes (Clarke, 2005; Golding, 2012). Protein displacement happens actively during aging at refrigerated temperature. The types of emulsifiers used, for example the different types of monoglycerides, affect the rate of protein displacement impacting the formation of fat aggregates during freezing. The fat aggregates then layered around and in between air bubbles protecting the foam structure. Good foam stability as impacted by the type of monoglycerides used lead to good meltdown resistance of the ice creams and frozen desserts at the same time imparts sensation of creaminess during consumption.

For the past decades, saturated monoglycerides have been widely used in ice cream and frozen dessert making. In the recent years, there is increasing number of studies applying unsaturated monoglycerides in ice creams (Zhang & Goff, 2005). Unsaturated monoglycerides has stronger surface reduction activity compared to saturated monoglycerides due to the difference in degree of unsaturation. Therefore, it encourages higher rate of protein displacement than saturated monoglycerides (Golding, 2012). Theoretically, unsaturated monoglycerides should be more potent in functionality as compared to the saturated

* Corresponding author. Knowledge & Discovery Application Centre, Futura Ingredients, Lot 11, Section 5, Fasa 2B, Pulau Indah Industrial Park, Jalan Sg. Pinang 4/2, 42920, Pulau Indah, Selangor. Malaysia.

E-mail address: lylee@futuraingredients.com (L.Y. Lee).

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version. In certain parts of the world, polysorbate 80 is added to saturated monoglycerides for enhancing performances. It is possible that unsaturated monoglycerides could perform as good as the blend of saturated monoglycerides with polysorbate 80, which is worth an investigation.

The triglycerides in dairy fats such as creams and anhydrous milk fats are rich in variations of fatty acids, typically with carbon chain length of C4, C6, C8, C10, C12, C14, C16 and C18, while vegetable fats such as palm have less variation of fatty acids, usually the C16 and C18 (Codex Alimentarius, 2015; Fonterra Co-operative Group, n. d.). However, vegetable fats, such as those from palm, palm kernel and coconut have now become a common fat source used in ice cream and frozen dessert globally as they have melting profiles similar to dairy fats (Clarke, 2005). The scope of the present study covers the use of vegetable fat in ice cream, which is termed frozen dessert. The objective of the study was to evaluate aeration stability of unsaturated against saturated monoglycerides in frozen dessert, and to investigate the potential uses of unsaturated monoglycerides as substitute to the blend of saturated monoglycerides with polysorbate 80 in frozen dessert. The physical properties of the frozen desserts were evaluated in terms of size and percentage of fat globules and aggregates, meltdown and heat shock resistances.

2. Materials and methods

2.1. Monoglycerides selection

A total of five types of emulsifiers, each at three dosage levels, *i.e.* 0.2, 0.3 and 0.4% were selected based on Zhang and Goff (2005) and internal product development research and development activities. The first two types were based on pure saturated monoglycerides. The other two were blends of unsaturated monoglycerides and the last was blended emulsifier commonly used in the making of ice cream and frozen dessert from saturated monoglycerides and polysorbate 80. The saturated monoglycerides were monoglycerides with minimum 55% monoglycerides, MDG, and self-emulsifying monoglycerides with minimum 45% monoglycerides and 4% soap content, SE MDG. MDG is commonly used in ice cream making, which is a reference of the present study. SE MDG was included to investigate if the presence of soap improves aeration enhancement or stability of monoglycerides in frozen desserts, as soap (sodium stearate) is added into monoglycerides to help dispersion and emulsification of the monoglycerides upon applications. The application of sodium stearate with monoglycerides is barely discussed in literature although it is practised (Hollis, 1995). The blended emulsifiers based on unsaturated monoglycerides were with different degree of unsaturation, *i.e.* Blend 1 at iodine value of 17–25 g I_2/100g and Blend 2 at 10–17 g I_2/100g. Blend 3 was saturated monoglycerides with polysorbate 80 at ratio of 80:20, having maximum iodine value of 6 g I_2/100g.

2.2. Ingredients and frozen dessert mix formulation

Frozen dessert formulation of 8% vegetable fat, approximately 3.1% protein content and 36% total solids was used in the study. The mix is composed of 8% hydrogenated palm kernel oil (HPKO) (Seocotine 314, Southern Edible Oil Industries (M) Sdn Bhd, Malaysia), 8.3% skim milk powder (SMP) (Skimmilk Powder Regular, Fonterra Cooperative Group Limited, New Zealand), 2.95% sweet whey powder (SWP) (Sweet Whey Powder, Euroserum, France), 12.5% crystalline sugar (Central Sugar Refinery Sdn Bhd), 4.5% glucose syrup 42 DE (San Soon Seng Food Industries Sdn Bhd), 0.2% stabilizers blend (locust bean gum, guar gum and carrageenan), and vanilla flavor. The ingredients were dosed at the same level in all samples except for emulsifiers which were evaluated at 0.2%, 0.3% and 0.4% and water to make up to 100%.

Water was added into a 10 L vessel of a batch pasteurizer (CKL Multimix, Malaysia) and heated to 50 °C. Glucose syrup was added, followed by SMP and SWP. Mixing was initiated at speed 1000 rpm. Half of the crystalline sugar was added directly into the vessel, while the other half was used to pre-blend emulsifier and stabilizers which were then added into the mix solution. HPKO was melted and added with mixing continued at 800 rpm and temperature elevated for pasteurization at 80 °C for 5 min. The mix was then homogenized at 190 bar (160 bar first stage, 30 bar stage) using a high pressure laboratory homogenizer (Twin Panda NS2002H, GEA Niro Soavi, Italy) and cooled to 5 °C in ice water bath prior transferred to the 4 °C chiller (MDS-1040R1, Modelux, South Korea) for aging overnight. In the next day, the mix was processed through the continuous ice cream freezer (MF-50, WCB Ice Cream, Denmark) to make frozen dessert. The parameters were controlled so that the frozen desserts were made to 100% overrun with drawn temperature of −5 °C. The frozen desserts were filled into paper containers of approximately 120 ml capacity and hardened in a blast freezer (E15-65, Tecnomac, Italy) to −24 °C, which were then transferred for storage in a −24 °C freezer (MDS-1040F1, Modelux, South Korea). Samples were stored for three days before evaluation started. The entire experiment was repeated once. Data reported are average of duplicated samples from the repeated experiment.

2.3. Evaluations of mix and frozen dessert properties

The mix samples stored overnight in a 4 °C Chiller (MDS-1040R1, Modelux, South Korea) were observed for stability (serum separation and protein precipitation) the following day. The mix was stirred manually for 1 min before sampling into 500 ml plastic container for viscosity measurement. Sample size was 450 ml at 7 ± 1 °C. Mix viscosity was measured using a viscometer (New DV2TLV, Brookfield, USA) with Spindle no. 3 (LV3) at test speed of 80 rpm.

Fat globules size distributions of the mix and frozen dessert were evaluated using a laser diffraction particle size analyzer, Malvern Mastersizer 3000 (Malvern Instruments, Ltd, United Kingdom) attached to the accessory, Hydro EV, for wet analysis. Fat globule size distributions of mix were measured after aging upon removal from storage of 4–5 °C, while frozen dessert was melted at 4–5 °C for 2 h prior measurement. Laser obscuration of 12–20% was set, with sample added to approximately 15% obscuration. Stirrer speed of 1500 rpm was used to disperse the samples. The refractive index set was 1.46 for fat and 1.33 for water as the dispersing medium, while the absorbance index was set at 0.01. Dilution of the mix and frozen dessert was approximately 1:1000 with distilled water. The results were analyzed using the software Mastersizer v2.20 (Malvern Instruments, Ltd, United Kingdom).

Two different sets of frozen dessert samples (75 ± 5 g) were prepared for meltdown resistance study. The first set of samples was stored at constant temperature of −24 °C in freezer (MDS-1040F1, Modelux, South Korea), while the second set of samples were exposed to temperature fluctuations for heat shock treatment. The heat shock samples were first kept for a week at −24 °C then exposed to ambient (approximately 26 °C) an hour a day for a total of 14 times.

The frozen dessert samples were transferred directly from the freezer on to 18 cm × 18 cm mesh grids (2 mm × 2 mm wire mesh) placed on 1 L glass beakers for meltdown resistance study in a 26 °C temperature controlled room. The weight of the melted samples was captured every 30 min for 4 h. The percentage of ice cream melted every 30 min was calculated by dividing the weight of melted ice cream over weight of the original ice cream sample and multiply by 100. The readings were then plotted on a curve of % melted ice cream over time and compared among samples. In addition, the meltdown rate of the samples was calculated as % over min (% min^{-1}).

Shape retention of the frozen dessert samples was evaluated qualitatively by capturing and comparing photos of the samples every 30 min throughout the 4-h test. Photos were taken using digital camera model Panasonic Lumix DMC-FT10S and saved in JPEG images.