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ScienceDirect
Agriculture and Agricultural Science Procedia 2 (2014) 191 – 198
Agriculture and Agricultural Science
Procedia

“ST26943”, 2nd International Conference on Agricultural and Food Engineering, CAFEi2014”

Saturated Distilled Monoglycerides Variants in Gel-form Cake Emulsifiers

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Abstract

Three palm based and one non-palm based saturated distilled monoglycerides (sDMG) were hydrated to form gels and applied into sponge cakes for performances evaluations. The gel structures were similar across the samples. The increase of gel dosage increased cake batter viscosity, aeration, cake specific volume and crumb softness. The performance of sDMG with high monopalmitin and high monostearin gel-form cake emulsifier in sponge cakes were of no significant difference ($P > 0.05$).

Keywords: Emulsifier; distilled monoglycerides; gel; cake

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1. Introduction

Distilled monoglycerides (DMG) is the most used food emulsifiers in the bakery segment. It is a further processed product from mono- and diglycerides (MDG). The economically feasible method of making MDG is through glycerolysis, which is the interesterification process of triglycerides and glycerol under high heat with presence of alkaline catalysts. DMG is obtained when MDG goes through the distillation process to segregate the monoglycerides to a concentration of 90 – 95% (Flack, 1976; Krog and Sparsø, 2004).

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doi:10.1016/j.aaspro.2014.11.027

The type of triglycerides used to manufacture monoglycerides could be of animal or plant origin, and could be products of hydrogenation or fractionation process to achieve desired level of saturation. The fully hydrogenated palm oil gives fully saturated palm oil while the fractionated gives palm stearin and palm olein (Basiron, 2005). The type of triglycerides used determines the characteristics of the emulsifier, such as fatty acid composition, iodine value and melting point. Monopalmitin (C16) and monostearin (C18) are two commonly available monoglycerides. Several extensive researches have been conducted to study commercial monoglycerides in water system (Krog and Larsson, 1968; Larsson et al., 1980; Richardson et al., 2002; Sein et al., 2002; Van de Walle et al., 2008a; Van de Walle et al., 2008b; Vereecken et al., 2009). Few researches were conducted on pure monoglycerides application. Langendijk and Pennings (1970) were one of the few that studied application of pure monoglycerides of different fatty acid chain length, C12 to C20. They found that monopalmitin and monostearin formed more complexes with starch components compared to monoglycerides of other chain length, in which monopalmitin formed the most complexes with starch components. The industry's preference of a higher monostearin over monopalmitin content in sDMG for aeration and crumb softness seems to contradict findings of Langendijk and Pennings (1970), in which monopalmitin was found better in crumb softening compared to monostearin. Vereecken et al. (2009) revealed that the only difference in crystallization and polymorphic behavior of monopalmitin and monostearin is the absence of the sub α-form crystalline structure that was only found in higher chain length monoglycerides, C18 onwards.

Monoglycerides are used in cakes for three purposes i.e. to facilitate emulsification of cake batter, aeration of cake batter, and crumb softening (Moonen and Bas, 2004; Orthoefer, 2008). Monoglycerides are functional only when it is present in its active alpha crystalline format. This is achieved by heating the monoglycerides to 5 to 10 °C above its melting point. In breadmaking, monoglycerides interact with starch components for crumb softening effect during the baking process (Moonen and Bas, 2004). However, in cake, the functional properties of monoglycerides are required at the mixing stage for aeration. Richardson et al. (2002) showed that the saturated distilled monoglycerides (sDMG) in β-crystalline form, its original solid powder form, did not function to aerate the batter at all. Therefore, emulsifiers are hydrated into gel-form, extruded or spray-dried on a carrier into powder to be able to be used directly in bakery applications. The use of alpha tending co-emulsifier, for instance polyglycerol esters (PGE), is required to retain monoglycerides in its active α-phase format. Another method of monoglycerides addition is through the fats and oils products used in the recipe, such as margarine and shortening (Moonen and Bas, 2004).

The main composition of gel-form cake emulsifiers are emulsifiers and water. Three liquid crystalline phases, lamellar, cubic and reversed hexagonal were observed in monoglycerides in water systems (Larsson et al., 1980). The desirable phase is the lamellar liquid crystalline phase which forms the active alpha crystalline gel upon cooling. Krog and Larsson (1968) showed that both ionic strength and pH influence the phase transition in a monoglyceride and water system. In a higher pH value of 8, a lower temperature of 50 °C compared to 53 °C at pH 7, is required to form the lamellar dispersion, while the presence of sodium chloride in the system increased the transition temperature. Van de Walle et al. (2008a) found that the addition of sodium soap, which functions as a co-emulsifier, preserved the lamellar dispersion of DMG, keeping the DMG stable in the α-gel state. Heertje et al. (1998) suggested that a balance of emulsifier, co-emulsifier, pH and ionic strength are required for optimum gel formation. This could be enhanced with the addition of polar solvents to decrease water phase polarity which helps to promote the formation of lamellar dispersion (Van de Walle et al., 2008b).

The objective of this research was to examine the performance of commercial sDMG in cakes emulsifiers. The sDMG selected comprised of different levels of monopalmitin and monostearin from palm and non-palm sources. They were first prepared into gel-form and applied into sponge cakes for performance evaluations.

2. Materials and methods

2.1. Emulsifiers

The palmitic (C16:0), stearic (C18:0), oleic (C18:1), linoleic (C18:2) and linolenic (C18:3) acid content in palm stearin, palm oil and soya bean oil are given in Table 1 (Codex Alimentarius, 1999). Hydrogens from the hydrogenation process saturate the double bonds, converting the unsaturated fatty acids into saturated fatty acids (Anderson, 2005). The monopalmitin and monostearin levels in the emulsifiers studied varied following its triglycerides sources, which were fully hydrogenated palm stearin, HPST, fully hydrogenated palm oil, HPO, blend of fully hydrogenated palm stearin with fatty acid, HPST+FA, and a sDMG from non-palm, fully hydrogenated soya bean oil, HSBO (Ekömul MG 95 series, Futura Ingredients Singapore Pte. Ltd., Singapore). The properties of these four emulsifiers are tabulated in Table 2, where the monopalmitin (C16) level decreased while the monostearin (C18) level increased from HPST to HSBO.

Table 1. Fatty acid composition of palm stearin, palm oil and soya bean oil extracted from Codex Alimentarius (1999).

Fatty Acid	Palm Stearin	Palm Oil	Soya Bean Oil
C16:0	48.0-74.0	39.3-47.5	8.0-13.5
C18:0	3.9-6.0	3.5- 6.0	2.0-5.4
C18:1	15.5-36.0	36.0-44.0	17-30
C18:2	3.0-10.0	9.0-12.0	48.0-59.0
C18:3	ND-0.5	ND-0.5	4.5-11.0

ND - non detectable, defined as ≤ 0.05%.

Table 2. Properties of saturated distilled monoglycerides studied.

Product Name	HPST	HPO	HPST+FA	HSBO
Source	Palm	Palm	Palm	Non-Palm
Iodine Value (g I_2/100g)	≤2	≤2	≤2	≤2
Melting Point (°C)	≈ 65	≈ 66	≈ 67	≈ 69
% Monoglycerides	≥95.0	≥95.0	≥95.0	≥95.0
% Monopalmitin (C16)	58.5 – 64.5	36.5 – 42.5	31.5 – 37.5	13.5 – 19.5
% Monostearin (C18)	33.5 – 39.5	54.5 – 60.5	60.0 – 66.0	79.0 – 85.0

2.2. Preparation of gel-form cake emulsifiers

Three vessels, A, B and C, a hot water bath, a hot plate (Fisher, United Kingdom), and a laboratory high shear mixer (2003SV, CKL Multimix Sdn. Bhd., Malaysia) were used to prepare the cake emulsifier in gel-form. The formulation of the cake emulsifier was 15% sDMG, 10% polyglycerol esters (Ekölite PE 03 P, Futura Ingredients Singapore Pte. Ltd., Singapore), 20% sorbitol (Cargill Inc., USA), 10% propylene glycol (Lyondell Chemical Company, USA), 10% refined glycerol (KL-Kepong Oleomas Sdn. Bhd., Malaysia), 0.8% sodium stearate (Peter Greven Asia Sdn. Bhd., Malaysia), 0.5% potassium hydroxide (UNID, Korea), 0.15% food grade refined salt (Seng Hin Brothers Enterprises Sdn. Bhd., Malaysia) and 33.55% water. The emulsifiers and sodium stearate were measured and transferred into vessel A. In vessel B, sorbitol, propylene glycol and glycerol were mixed. Potassium hydroxide, salt and water were measured and filled into vessel C. The vessels were heated to elevate the temperature of the ingredients to 95 ± 2 °C upon which vessel A was removed from the hot water bath and placed on the hot plate where temperature was maintained at 95 ± 2 °C. Ingredients in vessel B were transferred into vessel A and mixed at 500 rpm for one minute. Ingredients from vessel C were then added and mixing continued at 1,500 rpm for five minutes. Mixing speed was reduced to 300 rpm and continued for another 20 minutes after which heat source was terminated and mixing continued until the temperature reduced to 88 ± 1 °C. Foam surfaced to the top was removed. The mixture was transferred into plastic containers and left to cool and set at ambient condition before storing at 20 °C.

2.3. Polarised light microscopy

A polarized light microscope model BX43-32P01 (Olympus, Japan) equipped with a high resolution digital camera model TP-051000 and 4x objectives were used to study the structure of the gel-form cake emulsifiers. A thin layer of gel was smeared onto the object glass and heated for 2 minutes on a hot plate set at 50 °C. The object glass was transferred immediately to the specimen holder for microscopy evaluation.

2.4. Sponge cake making

The cake flour (Gold Key, FFM Berhad, Malaysia) used had protein content 7.0 – 9.5%, moisture content maximum 14%, ash content of maximum 0.55% and chlorination pH of 4.5 – 5.2. Eggs and castor sugar used were purchased from a local ingredient wholesaler. The sponge cake formula, based on 100% flour weight was 120% egg, 100% castor sugar, 50% water, and gel-form cake emulsifier at three dosage levels, 3%, 6%, and 9% of flour weight. As the industry recommended application dosage of gel-form cake emulsifier based on % egg weight, the dosage levels when translated were 2.5%, 5.0%, and 7.5% egg weight respectively. In the following discussion, the dosages were labeled as 2.5%, 5.0%, and 7.5% for ease of reporting. Sponge cake without gel-form cake emulsifier was prepared as control.

The single step continuous all-in method was applied. All the ingredients were added into the mixing bowl of a 3-speed planetary mixer (Murni Bakery Equipment, MBE-201LP, Taiwan) and mixed at speed-1 for 30 seconds. The mix was disengaged from the side of the mixing bowl and whipped at speed-3 for 3 minutes, followed by speed-2 for 15 seconds. Cake batter was scaled into cake tins of 8” diameter, and baked at 190 °C (top and bottom) for 25 minutes in an electrical oven (Murni Bakery Equipment, MBE-201SE-Z, China). After baking, the cakes were removed from the tins and left to cool at ambient for 2 hours prior packing in zipped bags.

2.5. Evaluations of batter and cakes

Batter specific gravity was calculated by dividing the weight of batter over weight of an equal volume of distilled water. The cake batter viscosity was measured using a viscometer (New DV2TLV, Brookfield, USA) immediately after mixing was completed. Cake batter was transferred into a 500 ml beaker up to a level marked near the brim. Spindle No. 4 and test speed of 15 rpm were used to determine the viscosity at room temperature of 26 °C.

The cake specific volume (cm^3/g) was determined by calculating cake volume over cake weight. Cake volume was measured by seed displacement method, while cake weight was measured using a digital balance. The sponge cakes were sliced into half to capture crumb structure images using a digital camera (Panasonic Lumix DMC-FT10S) and saved in JPEG images. The images of the sliced cakes were cropped and enlarged at the same scale for visual comparison. A texture analyser (TA.XT Plus, Stable Micro Systems, United Kingdom) with attachment of a 36 mm diameter cylindrical probe and equipped with software Texture Exponent 32 (version 6.1.2.0) was used to determine cake crumb firmness. Cakes samples were sliced into 5.0 cm x 5.0 cm x 3.5 cm. The pre-test speed was set at 1.0 mm/s, test speed at 1.7 mm/s and post-test speed at 10.0 mm/s. The force at 25% strain level was translated into crumb firmness automatically by the software. The outcome indicated the force required to compress the cake sample to 25% strain, therefore a higher force reading indicated firmer cake crumb.

Statistical analysis was performed using SPSS (Statistics 17.0, IBM, USA). A one-way analysis of variance (ANOVA) followed by the Tukey test was used to determine significant differences of the samples mean values at 95% confidence level.

3. Results and discussion

3.1. Gel preparation and structure

Preliminary studies in making the gels showed that a low gel pH, near neutral, and the absence of sodium stearate produced less stable gels, where transformation from α-gel to a more stable coagel occurred after one to two weeks’ storage. Potassium hydroxide was required to regulate pH of the gel, while sodium stearate was required to retain DMG in its active α-format (Van de Walle et al., 2008a), and also to improve the dispersibility of the α-tending emulsifier, polyglycerol esters (PGE) by solubilising the hexagonal phase formed when PGE was mixed with water (Krog and Sparsø, 2004). As suggested by Heertje et al. (1998), a balance of emulsifier, co-emulsifier, pH and ionic strength are required for optimum gel formation. Therefore, sodium stearate, potassium hydroxide and salt were added in the formulation to facilitate gel formation. Van de Walle et al. (2008b) suggested that the use of polar solvents supported the formation of lamellar dispersion, which in this study a combination of propylene glycol, sorbitol and glycerol was used.

The gels were prepared at a high speed 1,500 rpm as this was required to facilitate dispersion of the ingredients. The incorporated air during the high speed mixing was eliminated by mixing at reduced speed, 300 rpm towards the last 20 minutes of mixing. The elimination of air bubbles was a critical step as air bubbles in gel accelerate the transformation of α-gel to the non-active coagel (Moonen and Bas, 2004). The pH of the gels prepared fell within the range of 7.8 – 8.2, which met the pH range suggested by Krog and Larsson (1968) in forming lamellar dispersion at a lower temperature. The gels prepared in this study were observed for four weeks to ensure α-gel stability prior use in for baking test and evaluations.

Fig. 1 shows the micrographs structures of the gels with similar streaky trend although they were smeared in slightly different directions on the object glass. The crystals formed were very similar in the four samples and there was no distinct differences observed. Richardson et al. (2002) and Van de Walle et al. (2008a) also observed streaky α-structure in their studies of monoglycerides in aqueous systems.

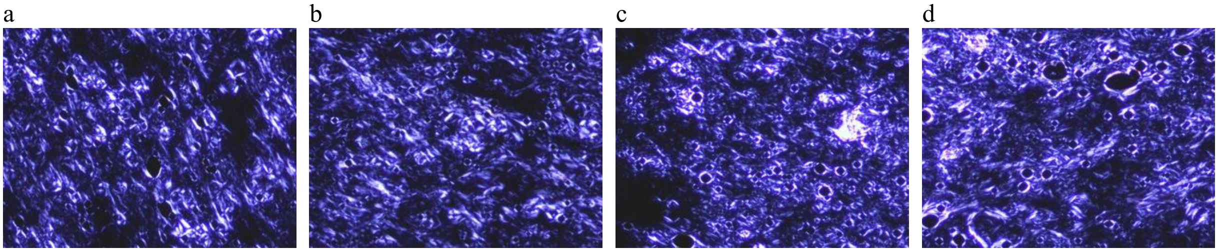

Fig. 1. Structure of gel-form cake emulsifiers formulated with sDMG from (a) HPST, (b) HPO, (c) HPST+FA, and (d) HSBO.

3.2. Sponge cake batter evaluations

Cake emulsifier was essential in the sponge cake formulation, where performances of cake batter viscosity (Fig. 2(a)), aeration (Fig. 2(b)) and sponge cake specific volume (Fig. 3(a)) and crumb softness (Fig. 3(b)) improved as the dosage of emulsifier increased. However, differences among sponge cakes made using gels from the four sDMG variants was not significant ($P > 0.05$) and therefore it could be assumed that the four sDMG studied performed equally well.

Cake batter of the control sample was extremely fluid compared to cake batter with cake emulsifiers (Fig. 2(a)). At 2.5% and 5.0% dosage, sample HPO and HSBO, respectively, gave higher batter viscosity ($P < 0.05$) compared to the other samples. At 7.5% dosage, sample HSBO had significantly higher batter viscosity than sample HPO ($P = 0.0001$) while sample HPST and HPST+FA had batter viscosity similar to both HPO and HSBO samples. In terms of batter aeration (1/specific gravity), samples with cake emulsifiers were much well aerated compared to the control (Fig. 2(b)). At 2.5% dosage, sample HPST was significantly denser than the other samples ($P < 0.05$), while at 5.0% dosage, its aeration was not different with sample HPO ($P = 0.995$), and faired poorer than samples HPST+FA ($P = 0.002$) and HSBO ($P = 0.000$). Sample HPO showed similar aeration performance to sample HPST+FA ($P = 0.059$) and performed poorer than sample HSBO ($P = 0.001$). Sample HPST+FA showed similar aeration performance with sample HSBO ($P = 0.999$). In general, at 5.0% gel dosage, which is also the industrial's recommended dosage, aeration performance was better from HSBO to HPST. At 7.5% dosage, all four gel samples showed equal performance in batter aeration ($P > 0.05$).

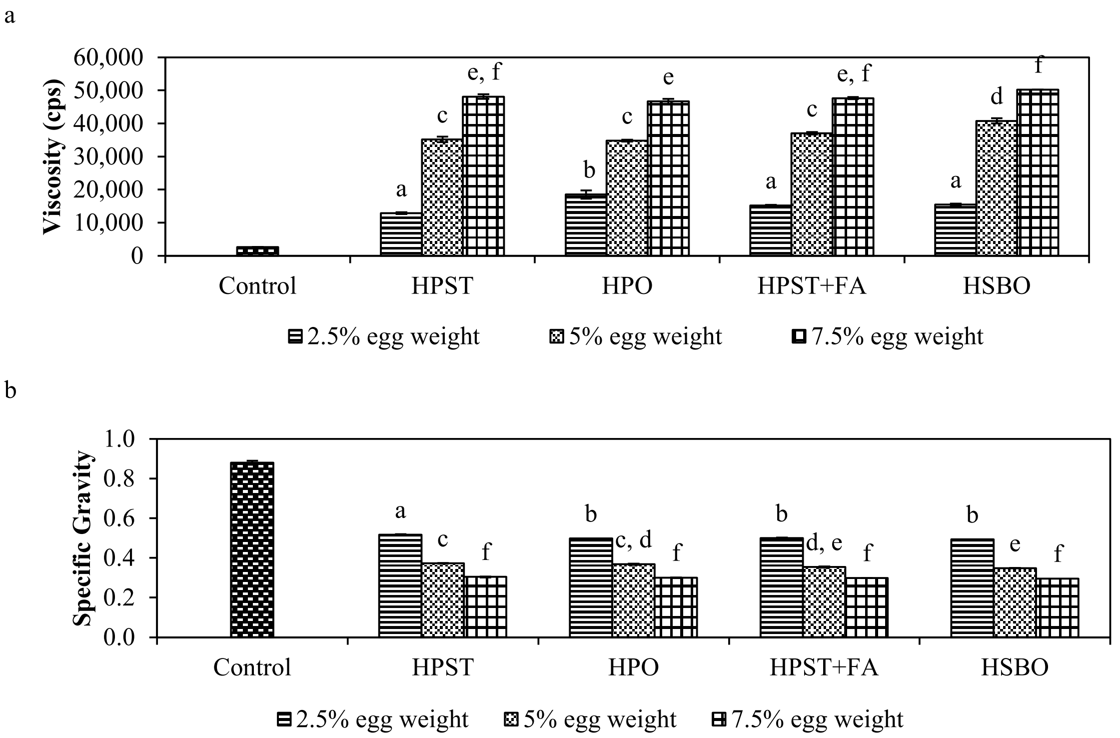

Fig. 2. Sponge cake batter (a) viscosity and (b) specific gravity of 2.5%, 5.0% and 7.5% egg weight dosage gel-form cake emulsifier. Viscosity of cake batter without gel-form cake emulsifier was 2,626.1 ± 53.7 cps; specific gravity was 0.88 ± 0.01. The different alphabets on top of the chart bar indicated statistical significance ($P < 0.05$).

3.3. Sponge cake quality evaluations

The slight differences observed in the batter viscosity and aeration was not reflected in specific volume (Fig. 3(a)) and crumb softness (Fig. 3(b)) of baked cakes. Control sample was smaller compared to any of the sponge cakes with cake emulsifier. Generally, specific volume of the sponge cakes increased significantly as the gel dosage increased ($P < 0.05$) and the four sDMG performed with no significant differences ($P > 0.05$). Sponge cakes baked using 7.5% gel HSBO had similar specific volume to 5.0% gel HPST+FA ($P = 0.991$). This usage of high emulsifier dosage at 7.5% may have limited air bubbles diffusion and suppressed cake expansion during baking (Sahi and Alara, 2003). During batter mixing, aeration occurs as air is incorporated into the aqueous phase of the batter forming thin films of foam. The presence of emulsifiers lowers the surface tension of the aqueous phase allowing increased amount of incorporated air. The viscosity of the batter increased as air is incorporated, in which high batter viscosity is important to regulate air bubbles in the batter to retain occluded air during early stages of baking (Gomez et al., 2007). Nonetheless, a too high dosage of emulsifier could have led to high batter viscosity which limits the availability of the thin films that regulate air bubbles diffusion, therefore limit the expansion of the cake during baking (Sahi and Alara, 2003).

While cake crumbs were significantly softer as dosage of gel increased ($P < 0.05$), the control sample was more than threefold harder compared to any of the samples with cake emulsifier (Fig. 3(b)). Apart from HPST at 2.5% dosage that was significantly harder than HSBO ($P = 0.0005$), the other sponge cakes did not show significant differences among the sDMG variants at each gel dosage ($P > 0.05$). The increase of gel dosages from 2.5% to 5.0% has reduced crumb softness by 48.2 – 50.9%, whereas for increase of gel dosage from 5.0% to 7.5%, crumb firmness reduced by 18.7 – 29.0%. This is consistent with crumb images observed in Fig. 4 where sponge cakes with 2.5% dosage was coarser with visible air pockets and the 5.0% dosage had crumb structure closer to samples with 7.5% dosage. The overall outcome of this study suggested that the four sDMG performed equally well in gel formats and sponge cake applications despite the different levels of monopalmitin and monostearin.

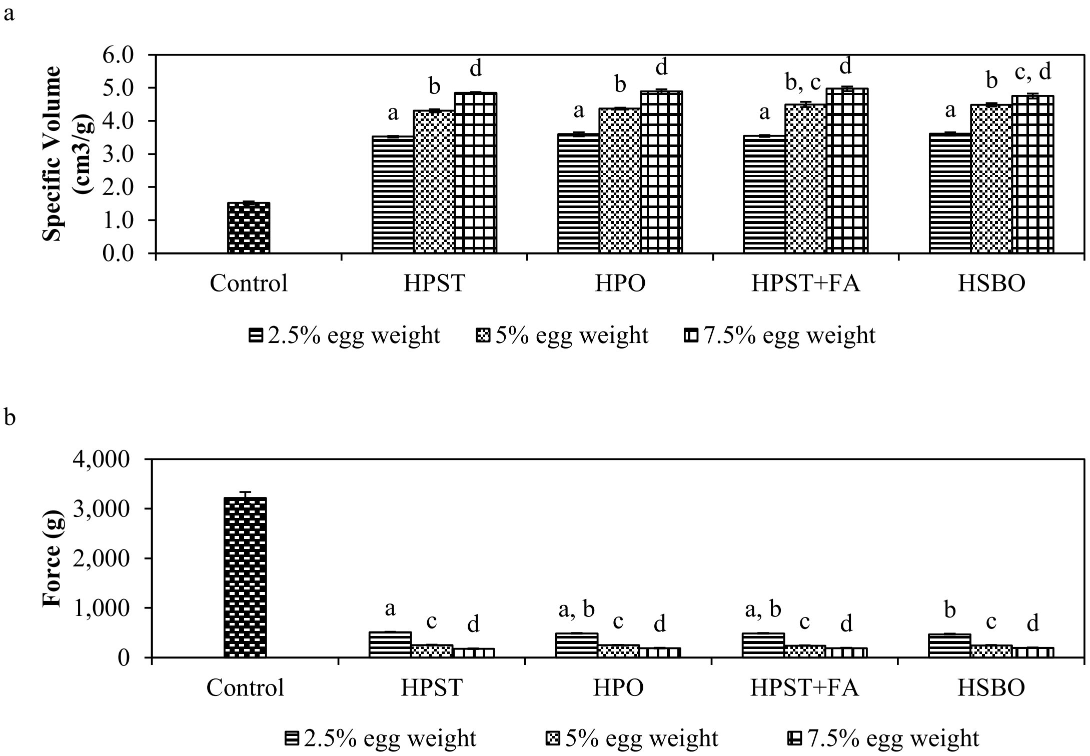

Fig. 3. Sponge cakes (a) specific volume, and (b) crumb softness at 2.5%, 5.0% and 7.5% egg weight dosage gel-form cake emulsifier. Specific volume of sponge cakes without gel-form cake emulsifier was 1.52 ± 0.05 cm3/g; crumb softness was recorded at 3,217.2 ± 120.6 g. The different alphabets on top of the chart bar indicated statistical significance ($P < 0.05$).

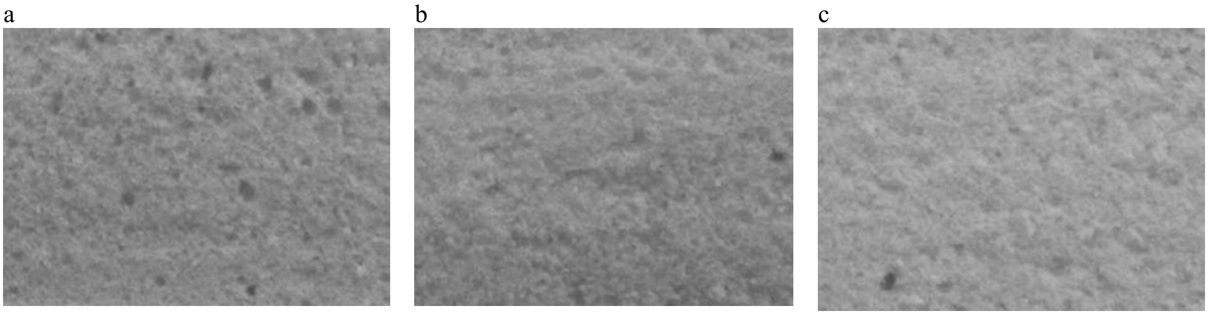

Fig. 4. Crumb structure of sponge cakes with different dosage levels of gel-form cake emulsifier formulated with sDMG from HPST+FA: (a) 2.5% egg weight; (b) 5.0% egg weight; and (c) 7.5% egg weight.

4. Conclusions

The emulsifier variants demonstrated similar structures in gel-form cake emulsifiers with no significant differences observed in sponge cakes qualities. Emulsifier which is higher in monopalmitin content performed as good as emulsifier with higher monostearin content in terms of cake batter viscosity and volume of cakes and its crumb hardness except for slightly better aeration performance by the high monostearin sDMG at 5% usage.

Acknowledgements

The authors thank Matrix Optics (M) Sdn. Bhd. for the use of microscope and the micrographs.

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Accepted for oral presentation in CAFEi2014 (December 1-3, 2014 – Kuala Lumpur, Malaysia) as paper 244.