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Effect of three plant-based shortenings and lard on cookie dough properties and cookies quality

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Abstract

Tropical fats such as palm oil (PO) from *Elaeis guineensis* (oil palm), cocoa (*Theobroma cacao* L.) butter (CB), avocado (*Persea americana*) oil (Avo), palm stearin (PS), and *Mee* (*Madhuca longifolia*) fat (MF) are useful raw materials for the formulation of bakery shortenings. Blending these fats at differing ratios such as binary [MF:PS (99:1)], ternary [Avo:PS:CB (84:7:9)], and quaternary [PO:PS:SBO:CB (38:5:52:5)] would lead to fat mixtures as replacement for lard (LD). In the present work, the influence of these three fat blends and LD on cookie dough textural properties and cookie quality was investigated. The results showed that the hardness of cookies was correlated to the hardness of dough, which was influenced by the solid fat content (SFC). The degree of unsaturation of triacylglycerol molecules also seemed to influence these parameters. Nevertheless, the cookies of all different types of shortenings did not show any significant differences with regard to their width and thickness. This could be probably due to the fact that cookies made from formulated plant-based shortenings and LD expanded uniformly during baking.

Introduction

Cookies are among the most favourite snacks enjoyed by people of all ages, ethnicities and cultures. They are baked items made of wheat flour, sugar and fat. Most cookies are formulated with about 10 to 30% of shortening made from either plant or animal fat. In dough development, shortening plays an important role as it interacts effectively with the protein and starch matrix to prevent excessive development of gluten during mixing (Fustier *et al.*, 2008). During dough making, shortening is also believed to act as a lubricating agent as well as contributing to aeration to entrap and retain air (Given, 1994). According to Baltsavias *et al.* (1997), substitution of shortenings with liquid oils or effort to reduce fat content might decrease dough stiffness, which might produce distorted greasy cookies. For this reason, O'Brien (2008) stated that solid fat content (SFC) of shortenings has strong relationship with product performance at the temperature in which the cookie is baked. For instance, shortenings with high SFC do

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not have enough liquidity for aeration while those with low SFC do not have the ability to hold the air until mixing is complete. The incorporation of shortening may also help reduce stickiness of starchy foods, while improving freeze-thaw stability, and retarding staling of cookies (Copeland *et al.*, 2009). Apart from this, shortening could impart desirable quality attributes to the texture and flavour of baked products (Jacob and Leelavathi, 2007; O'Brien, 2008; Seker *et al.*, 2010).

The study of the functional roles of lipids on structural and textural properties of dough and cookie development has drawn the attention of many researchers (Arifin *et al.*, 2010). According to Baltsavias *et al.* (1999), fat plays an important role in the mechanical properties and fracturing behaviour of cookies. It is generally agreed that fats of different types such as butter, palm olein, palm stearin, and palm mid-fraction differently affect textural properties of cookie dough (Mamat and Hill, 2014). For instance, Maache-Rezzoug *et al.* (1998) found that the addition of solid fat usually softens the dough and decreases the viscosity. They further stated that this contributed to an increase in length and decrease in weight and thickness of cookies. In this regard, a discussion on the influence of plant- and animal-based fats on cookie properties is worthy of consideration. In a previous investigation, Yanty *et al.* (2014) observed that cookie lipids formulated with palm-based fats and LD displayed differing thermal behaviours owing to their compositional differences. Since the inclusion of lard (LD) in cookie formulations is usually prohibited in *halal* and kosher food regulations, researchers have attempted to develop binary [MF:PS (99:1)], ternary [Avo:PS:CB (84:7:9)], and quaternary [PO:PS:SBO:CB (38:5:52:5)] plant-fat mixtures as alternatives (Yanty, 2016). Since these investigations did not go beyond mere comparison of the composition and thermal behaviour of lipids, it is necessary to study the influence of the formulated novel fat mixtures on the characteristics of finished products. Hence, the objective of the present work was to compare the performance characteristics of the binary [MF:PS (99:1)], ternary [Avo:PS:CB (84:7:9)], and quaternary [PO:PS:SBO:CB (38:5:52:5)] fat mixtures in terms of cookie dough properties and cookie quality.

Materials and methods

Research materials

For cookie dough preparation, wheat flour, sucrose, salt, and sodium bicarbonate were used. Commercial wheat flour was purchased from Paniflower stores, Ghent, Belgium. Salt, sodium bicarbonate, and sucrose were purchased from a local supermarket in Malaysia. Adipose tissues of swine were collected in three batches from local slaughter houses to extract the LD following the method reported previously by Marikkar *et al.* (2001). Avocado fat was extracted using avocado fruits collected from West Malaysia and *Mee* fat was extracted from dried fruit seeds of *Madhuca longifolia* collected from Sri Lanka. Samples of palm oil and palm stearin were obtained from the Malaysian Palm Oil Board, Bandar Baru Bangi, Selangor, Malaysia. Samples of cocoa butter were purchased from Malaysian Cocoa Board, and samples of soybean oil were obtained from Sime Darby Food Marketing Sdn. Bhd., Selangor, Malaysia.

Blend formulation and preparation

Firstly, the fat blends namely binary [MF:PS (99:1)], ternary [Avo:PS:CB (84:7:9)], and quaternary [PO:PS:SBO:CB (38:5:52:5)] were prepared using raw oils and fat samples by giving consideration to their SFC profiles. All fats were heated at 70°C until completely melted to erase their crystal memory present in the matrix systems.

Preparation of shortening

Shortenings were produced following the method described by Braipson-Danthine *et al.* (2005). In order to erase the crystal memory, a 500 g sample of individual fat blend was melted at 70°C for 10 min. A pre-cooling stage was introduced at 50°C for 15 min, before each blend was crystallised under shear at 20°C and 125 rpm for 45 min. A 1.0 L jacketed glass reactor connected to a water-bath (Lauda, Germany) was employed to perform this procedure. The resulting slurry was transferred to a freezer at -20°C for 45 min to complete the crystallisation. Prior to analysis, the prepared shortening was kept in a thermostatic cabinet at 25°C ± 1°C for 24 h. The same procedure was repeated for all fat blends and LD.

Shortening analysis for TAG composition

Waters Model 2695 liquid chromatograph equipped with a differential refractometer Model 2414 as a detector (Waters Associates, Milford, MA) was used to determine the TAG composition of oil samples. All the instrumental conditions including the type of column were as described by Nur Illiyin *et al.* (2013). The identification of TAG peaks of samples was done using a set of TAG standards purchased from Sigma-Aldrich (Deisehofen, Germany) as well as the TAG profiles of LD, PS, and Avo, available from our previous study (Yanty, 2016).

NMR analysis of solid fat content

Solid fat content (SFC) measurement of samples was carried out using a Bruker Minispec (Model Mq 20) pulse Nuclear Magnetic Resonance (pNMR) spectrometer (Karlsruhe, Germany) following the AOCS Method Cd 16b-93 (AOCS, 2004). All the instrumental conditions including the sampling procedure were as described by Yanty (2016).

Cookie dough preparation

Cookie dough formulation was performed following AACC Method 10-50D (AACC, 2000) with slight changes. Shortenings of all fat blends were kept in a thermostatic cabinet overnight at 25°C ± 1°C before preparing the dough. The same temperature was maintained throughout the whole dough-making process. Firstly, individual shortening (64 g) was creamed with sugar (130 g), sodium bicarbonate (2.5 g), and salt (2.1 g) for 3 min at low speed in a mixer while scraping the bowl every minute. After adding 33 g of sucrose solution (5.9%, w/v) and 22.8 g of deionised water, mixing was continued using Kenwood mixer (Model KM200) for 2 min at high speed. After adding 218.2 g of wheat flour, mixing was continued for 2 min at low speed while scraping the bowl every 30 sec. Finally, the dough was allowed to rest for 10 min before further analyses.

Evaluation of consistency and elasticity of cookie dough

Cookie dough consistency as influenced by different shortenings was measured following the method of Olewnik and Kulp (1984) using a Brabender Farinograph (Model D-47055, Duisburg, Germany). After mixing, dough was allowed to rest for 10 min. Then, a piece of dough (300 g) was transferred into the farinograph bowl, set at a constant temperature (25°C) and mixed at 63 rpm for 20 min. Cookie dough consistency was recorded at 0 and 15 min of the mixing periods. Three independent batches were analysed for each individual fat blend.

Dough hardness evaluation

Dough was rolled and cut into dimensions of 45 mm diameter and 20 mm thickness. Evaluation of three discs were done using a texture analyser (TA-XT plus, Stable Microsystem, Surrey, UK) equipped with a cylindrical probe (75 mm diameter) and a 5 N load cell. The dough samples were compressed to reach 50% deformation at the test speed of 1 mm/sec. The maximum force was recorded to evaluate the dough hardness (Sciarini *et al.*, 2013).

Evaluation of dough setting time

A camera was positioned in the baking oven door at about 30 cm in front of the baking plate to film the baking process as a way to evaluate the dough setting time during baking. Photographed images were analysed at every 30 sec using Image J software 1.41° to calculate the changes in cookie width (National Institute of Health, USA).

Cookie preparation

Cookie preparation was performed following the AACC Method 10-50D (AACC, 2000) with slight changes. The dough was allowed to rest for 10 min before rolling-on and cutting (62 mm diameter, 5.5 mm thickness). The cut dough pieces were then baked for 13 min in a baking oven (MIWE Aero, Germany) at 205°C. The cooled cookies were left at 25°C for 30 min, and packed in sealed plastic bags until further analysis.

Evaluation of cookie width, thickness, and spread ratio

One hour after baking, cookie width (W) and thickness (T) were measured using a Vernier calliper to calculate the spread ratio (W/T). The width of six cookies was measured by laying them edge to edge. Next, cookies were re-measured by rotating at 90° to obtain the average width (W) of six cookies. The thickness of cookies was measured by stacking six cookies on top of one another. They were re-measured to obtain mean thickness value (T) of six cookies by restacking in different orders.

The spread factor calculation was performed following the AACC Method 10-50D (AACC, 2000) as shown below:

$$\text{Spread factor} = CF \times (W/T) \times 100 \qquad \text{(Eq. 1)}$$

where CF = correction factor for lab elevation and barometric pressure reading correlating to the sea level during baking (AACC, 2000), W = width, and T = thickness.

Evaluation of cookie hardness

Cookie hardness was evaluated after 24 h of baking with a texture analyser (TA.XT plus, Stable Microsystem, Surrey, UK) equipped with a 30 N load cell, using a three-point break (HDP/3PB) probe. Compression was applied until breaking at a speed of 1 mm/sec. The maximum force required to break the cookie was considered as a hardness parameter.

Statistical analysis

All measurements were carried out in triplicate (n = 3). All results from analyses were expressed as the mean value ± standard deviation. Data were analysed statistically by one-way analysis of variance (ANOVA) with IBM SPSS software package (version 21.0). When F values were significant, mean differences were compared using Duncan's multiple range tests at the 5% level of probability.

Table 1. Hardness, consistency, and elasticity of cookie dough made from different shortening types.

Shortening	Hardness (g)	Consistency (BU)		Elasticity (BU)
		At 0 min	At 15 min	
Binary shortening	231.56 ± 3.45[c]	187.0 ± 0.09[a]	337.0 ± 0.08[c]	65.0 ± 0.20[b]
Ternary shortening	224.65 ± 2.44[b]	245.0 ± 0.05[c]	360.0 ± 0.16[d]	71.0 ± 0.16[c]
Quaternary shortening	218.33 ± 2.89[a]	186.0 ± 0.12[a]	300.0 ± 0.10[a]	52.0 ± 0.14[a]
LD shortening	219.29 ± 3.01[a]	215.0 ± 0.04[b]	333.0 ± 0.21[b]	63.0 ± 0.18[b]

LD: lard. Data are means of three determinations (n = 3). Means within each column bearing different superscripts are significantly different (p < 0.05).

Results and discussion

Cookie dough properties

The hardness values of cookie dough formulated with shortenings of different types are shown in Table 1. In baking, shortenings contribute to product characteristics such as tenderness, flavour, mouthfeel, lubricity, structure, and shelf life. According to previous reports, different types of shortenings used might affect dough properties to different extent. Hardness of dough, for instance, was as an important quality attribute, which was measured in many previous studies (Karaoğlu and Kotancilar, 2009). Based on the results in Table 1, cookie dough made from binary shortening was the hardest (231.56 g) since it required more force to compress. This could probably be due to PS and MF components, which are hard in nature due to dominance of di-saturated (40.97%) and tri-saturated (1.38%) molecules (Table 2). Previous study by Podchong *et al.* (2018) also showed that di- and tri-saturates of PS were more than 60% of the total TAG molecular distributions. Dough made from LD was the softest (218.33 g) since its compression required the least force. This soft nature could be due to the presence of low amounts of di-saturated (26.6%) and tri-saturated (2.50%) molecules (Table 2). The hardness values of cookie doughs made from the rest of the two shortenings were between these two extremes. Based on statistical analysis, the hardness values of all cookie dough made from formulated plant-based shortenings and LD were significantly (p < 0.05) different. This could probably be due to slightly differing nature of SFC profiles of these fats and LD at the working temperature. For instance, the SFCs of the formulated fat mixtures and LD were found to range from 20.00% (in binary mixture) to 24.58% (in LD) at 15°C (Table 3). According to Jin *et al.* (2018), SFC was found to correlate with the textural and sensorial properties of fat-containing foods. It could be possible that cookie dough made from LD and quaternary shortenings were more cohesive and viscous thus leading to a softer texture.

Table 3. SFC values of binary, ternary and quaternary shortenings, and lard.

Temp (°C)	MF:PS (99:1)	Avo:PS:CB (84:7:9)	PO:PS:SBO:CB (38:5:52:5)	LD
0	35.18 ± 1.07[ab]	33.57 ± 0.94[b]	33.15 ± 1.21[b]	32.19 ± 0.03[b]
5	30.68 ± 0.70[a]	30.10 ± 0.17[c]	30.79 ± 0.78[a]	30.62 ± 0.03[c]
10	25.08 ± 0.60[a]	24.74 ± 0.50[c]	24.79 ± 0.57[a]	27.66 ± 0.04[b]
15	20.00 ± 0.44[a]	21.14 ± 0.30[d]	20.43 ± 0.43[a]	24.58 ± 0.11[c]
20	17.27 ± 0.38[ab]	18.20 ± 0.41[c]	16.21 ± 0.40[a]	19.80 ± 0.00[c]
25	13.50 ± 0.67[a]	14.11 ± 0.72[c]	12.47 ± 0.23[a]	13.52 ± 0.14[c]
30	8.86 ± 0.08[c]	9.31 ± 0.05[d]	7.83 ± 0.11[b]	3.20 ± 0.14f
35	4.32 ± 0.03[b]	2.41 ± 0.04[c]	6.49 ± 0.07[c]	2.21 ± 0.00[c]
40	0.07 ± 0.00[b]	1.53 ± 0.01[b]	3.03 ± 0.04[c]	1.01 ± 0.01[d]
45	0	0.53 ± 0.00[b]	0	0
50	0	0	0	0

Avo: avocado oil; CB: cocoa butter; LD: lard; PO: palm oil; PS: palm stearin; SBO: soybean oil. Means within each column bearing different superscripts are significantly different (p < 0.05).

Consistency is the next important property connected to dough development for cookies. The farinograph dough consistency recorded for pre-mixed cookie dough at 0 and 15 min of mixing time are presented in Table 1. Generally, the bigger the Brabender Unit (BU), the stiffer the dough consistency (Olewnik and Kulp, 1984). As shown in Table 1, the dough made from formulated plant-based shortenings and LD had better consistencies with increasing mixing time. This increase in consistency could be attributed to the gluten development during

Table 2. TAG composition of binary, ternary and quaternary shortenings.

TAG	MF:PS (99:1)	Avo:PS:CB (84:7:9)	PO:PS:SBO:CB (38:5:52:5)	LD
LLnLn	n.d.	n.d.	0.70 ± 0.01[b]	n.d.
LLLn	n.d.	1.56 ± 0.01[a]	3.93 ± 0.01[b]	1.54 ± 0.21[a]
OLnLn	n.d.	n.d.	0.01 ± 0.00[a]	n.d.
LLL	n.d.	0.58 ± 0.04[a]	12.23 ± 0.00[b]	0.68 ± 0.21[a]
PLLn	n.d.	n.d.	1.90 ± 0.01[a]	n.d.
OLL	0.51 ± 0.01[a]	2.72 ± 0.03[b]	9.28 ± 0.01[c]	4.68 ± 0.08[c]
MMM	n.d.	n.d.	0.16 ± 0.01[a]	n.d.
PLL	0.43 ± 0.01[a]	3.58 ± 0.01[b]	8.23 ± 0.04[d]	7.05 ± 0.06[c]
MPL	n.d.	n.d.	0.19 ± 0.01[a]	n.d.
POLn	n.d.	n.d.	0.06 ± 0.00[a]	n.d.
OOL	2.91 ± 0.03[a]	6.98 ± 0.07[c]	5.58 ± 0.00[b]	6.93 ± 0.04[c]
POL	5.11 ± 0.04[a]	16.18 ± 0.05[c]	11.31 ± 0.01[b]	20.00 ± 0.27[d]
PPL	1.66 ± 0.01[a]	2.62 ± 0.01[b]	5.02 ± 0.01[c]	2.62 ± 0.04[b]
OOO	9.11 ± 0.06[c]	9.62 ± 0.05[c]	3.14 ± 0.00[a]	4.33 ± 0.18[b]
POO	23.56 ± 0.04[c]	19.36 ± 0.03[b]	10.87 ± 0.03[a]	20.67 ± 0.11[b]
PPO	15.29 ± 0.21[c]	13.28 ± 0.04[b]	13.48 ± 0.02[b]	10.63 ± 0.01[a]
PPP	2.51 ± 0.03[b]	7.07 ± 0.01[d]	4.90 ± 0.06[c]	0.38 ± 0.01[a]
SOO	9.84 ± 0.11[d]	0.71 ± 0.01[a]	1.85 ± 0.05[b]	3.62 ± 0.04[c]
SPO	18.41 ± 0.12[d]	10.56 ± 0.06[b]	4.58 ± 0.10[a]	12.52 ± 0.12[c]
PPS	0.70 ± 0.01[a]	0.79 ± 0.01[a]	0.86 ± 0.01[a]	0.81 ± 0.00[a]
SOS	5.61 ± 0.04[d]	3.54 ± 0.01[c]	1.59 ± 0.03[b]	0.83 ± 0.01[a]
SSS	0.59 ± 0.01[b]	0.21 ± 0.00[b]	0.02 ± 0.00[a]	1.31 ± 0.01[c]
Others	3.71 ± 0.02[c]	0.69 ± 0.33[a]	n.[d].	1.41 ± 0.05[b]
UUU	12.53	21.46	34.89	18.16
UUSt	38.92	39.83	34.22	51.34
UStSt	40.97	30.00	24.86	26.60
StStSt	1.38	8.07	5.94	2.50

Avo: avocado butter; MF: mee fat; TAG: triacylglycerol; PO: palm oil; PS: palm stearin; SBO: soybean oil; CB: cocoa butter; LD: lard; O: oleic; P: palmitic; L: linoleic; Ln: linolenic; St: stearic; U: unsaturated; S: saturated; n.d.: not detected. Data are means of two determinations ($n = 2$). Means within each row bearing different superscripts are significantly different ($p < 0.05$).

longer mixing period starting from 7 min in the mixer followed by 20 min in the farinograph. According to Jacob and Leelawathi (2007), the physical properties of cookie dough were heavily dependent on effective interaction between fat and water in the system. If the fat distribution in the cookie system was poor, flour particles will remain accessible to water which will result in the development of gluten proteins (Olewnik and Kulp, 1984). The development of more gluten proteins would make the dough more elastic so that baked product would become tougher. The dough made from LD shortening had a consistency value of 215 BU at 0 min which increased to 333 BU at the end of 15 min of mixing. The stiffest dough was made from ternary mixture shortening, which had 245 BU at 0 min and 360 BU at 15 min, while the least stiff was displayed by dough made from quaternary mixture, which had 186 BU at 0 min and 300 BU at 15 min (Table 1). Although dough made from binary shortening (337 BU) had a closer consistency value with LD (333 BU) at 15 min of mixing, the values were still significantly ($p < 0.05$) different. Likewise, the dough made from quaternary shortening showed the lowest (300 BU), but the value was not significantly ($p > 0.05$) different when compared to that of the dough made from LD shortening.

The dough of all formulated plant-based shortenings and LD showed sufficient resistance to mixing, as they were not broken down during mixing in the farinograph. Based on previous reports by Sciarini *et al.* (2013) and Jacob and Leelawathi (2007), the hardness, consistency, and elasticity of dough made from different shortenings correlated with the SFC profile of shortenings. For cookie making, highly elastic dough is not desirable as it might negatively affect the quality of the final product. Based on Table 1, dough made from ternary shortening was the most elastic (71 BU), while dough made from quaternary shortening was the least elastic (52 BU). The dough made from LD shortening had an elasticity of 63 BU while that made from binary shortening had an elasticity of 65 BU with no significant ($p > 0.05$) difference between them.

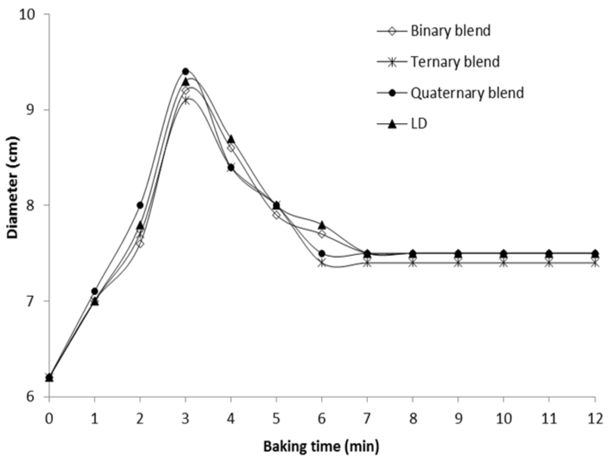

Figure 1. Effect of different types of shortening on cookie diameter while baking. LD: lard.

Cookie properties

The effect of oven-baking on cookie width is illustrated in Figure 1. This showed that cookies made from different shortening types displayed similar profiles of increasing and decreasing diameters. As a common feature, they all reached their respective maximum diameters at 3 min of baking. The maximum diameter value was found for cookies made from quaternary shortening while the minimum was for cookies made from ternary shortening at 3 min of baking. In the meantime, the diameters of cookies made from binary and LD shortenings were between these two extremes. The set time is the time at which dough spreading comes to a complete stop (Abboud *et al.*, 1985; Hoseney *et al.*, 1988). Cookie dough made from binary and LD shortenings were found to have their set times around 7 min while the cookie dough made from ternary and quaternary shortenings reached their respective set times at around 6 min. However, this difference might not be attributed to any of the differences in shortening types.

The data presented in Table 4 shows the width, thickness, and spread ratio of cookies made from different shortenings. All cookies displayed substantial increase in their diameter after baking. The cookie made from LD shortening had a width of 72.95 mm and a thickness of 9.42 mm. Based on ANOVA results, there were no significant ($p > 0.05$) differences among the cookies of all different types of shortenings with regard to width and thickness. Probably, the cookies made from formulated plant-based shortenings and LD shortening expanded uniformly, which could be due to the fact that they were similar in SFC at 25°C (working temperature) and texture. In a previous study, Kweon *et al.* (2010) also found that cookies baked with shortenings of similar solidification characteristics were not significantly different in their diameter, height, or weight loss during baking.

Table 4. Hardness, width, thickness, and spread ratio of cookies made from different shortening types.

Shortening	Hardness (g)	Width (mm)	Thickness (mm)	Spread ratio
Binary mixture	1028.12 ± 3.77[c]	72.69 ± 0.19[a]	9.32 ± 0.23[a]	7.80 ± 0.08[a]
Ternary mixture	1019.75 ± 4.64[b]	72.33 ± 0.25[a]	9.38 ± 0.18[a]	7.71 ± 0.05[a]
Quaternary mixture	1012.92 ± 3.42[a]	72.87 ± 0.12[a]	9.52 ± 0.02[a]	7.65 ± 0.02[a]
LD	1009.32 ± 3.65[a]	72.95 ± 0.27[a]	9.42 ± 0.11[a]	7.74 ± 0.07[a]

LD, lard. Data are means of three determinations ($n = 3$). Means within each column bearing different superscripts are significantly different ($p < 0.05$).

The mean spread of cookies made from formulated plant-based shortenings and LD are shown in Table 4. Spread ratio is a measure of the quality index of cookies using the cookie width to cookie thickness ratio (Swanson and Munsayac, 1999). Rogers (2004) stated that the incorporation of air is highly important in cookie development and therefore cookie spread ratio may be affected by the type of fat used in the formulation (Wainwright, 1999). Although Abboud *et al.* (1985) suggested that the type of triacylglycerol did not appear to be an important factor to influence the cookie spread ratio (Dinç *et al.*, 2014), other researchers expressed different opinions. Abboud *et al.* (1985) found that a higher amount of palm fat in the mixtures would cause higher spread ratio when compared to other types of fat. Based on Table 4, the spread ratio of cookies made from LD shortening was 7.74. The highest mean cookie spread ratio of 7.80 was found in cookies made from binary mixture shortening while the lowest mean cookie spread ratio of 7.65 was found in cookies made from quaternary mixture shortening (7.65). Nevertheless, based on ANOVA results, there were no significant ($p > 0.05$) differences in the mean cookie spread ratio of all cookies prepared from different shortenings. The least mean cookie spread ratio found for quaternary shortening was probably due to the ability to retain more water during baking that enhanced gluten development. The enhanced gluten development not only leads to a reduction of the cookie spread ratio but also changes the texture of cookies from snap to soft-batch type (Sikorski, 2004).

The hardness values of cookies made from formulated plant-based shortening and LD are shown in Table 4. The hardness of binary, ternary and quaternary shortenings and LD were 1028.12, 1019.75, 1012.92, and 1009.32 g, respectively. Based on ANOVA results, there was significant ($p < 0.05$) difference among hardness of cookies made from different plant-based shortenings. In fact, the hardness of cookies was directly related to the hardness of dough as seen previously in Table 1. For instance, cookie dough made from binary shortening was the hardest (231.56 g) while that made from LD shortening was the softest (219.29) owing to their slight differences in SFC profiles and distribution of mono-unsaturated (UStSt) and tri-saturated (StStSt) triacylglycerols (Tables 2 and 3). Other studies by Jacob and Leelawathi (2007) also indicated that the hardness of cookies was affected by SFC profile of the shortening used in formulations. Generally, the decrease in SFC at the working temperature would lead to a lowering of breaking strength of cookie.

Conclusion

The present work compared the performance characteristics of three formulated novel fat mixtures in cookie dough and cookie quality. The results showed that cookie dough made from MF:PS (99:1) was the hardest (231.56 g) while cookie dough made from LD shortening was the softest. The consistency of dough made from formulated fat mixtures and LD increased with continued mixing in farinograph; thus it was not broken down during the mixing time. In terms of cookie quality, cookies made from MF:PS (99:1) displayed the highest hardness value while that made from LD was found to have the lowest hardness. The set times of cookies prepared from MF:PS (99:1) and LD were 7 min while those of other shortening types were 6 min. However, there were no significant differences among the cookies of all fat mixtures with regard to width and thickness. This could be due to the fact that cookies made from formulated plant-based shortenings and LD shortening expanded uniformly during baking.

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