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Changes in the Quality Characteristics of White Bread Made Using Different Shortening Formulations During Storage

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Abstract: The objectives of this study were to determine the effects of different types of refined, bleached and deodorized (RBD) palm oil/palm stearin-based shortenings on the quality of white bread. For this purpose, shortenings of seven blends of RBD palm oil (PO) and palm stearin (PS) were used in the bread making experiment. Shortenings were blended in 100:0, 80:20, 60:40, 50:50, 40:60, 20:80 and 0:100 of PO:PS ratios, respectively. TheTriacylglycerols (TAG) of shortenings were investigated using high performance liquid chromatography (HPLC). In total, seven formulations of bread were prepared and bread made from 100:0 was used as a control, while those made without shortening were used as comparisons with other formulations. The breads were investigated at ambient temperature and using various aging times with DSC and texture analyzer (TA-XT2) to determine starch retrogradation and crumb firmness, respectively. Triacylglycerols, such as OOO, OOP and OOS, were found to decrease, while PPO increased due to the increase in the palm stearin content of the shortenings. During storage, DSC showed one endothermic peak for all aging times. The texture analyzer showed that the bread made from shortening formulation 100:0 had the least crumb firmness, while those made without shortening had the highest crumb firmness.

Key words: Shortenings · Triacylglycerols · White bread · DSC · Texture

INTRODUCTION

Several researchers [1-3] have indicated that bread staling include many types of alterations during storage, such as replacing fresh bread by stale bread flavour, loss of crispness in the crust and an increase of crumb firmness. Although it has been practiced for thousands of years, bread staling is a phenomenon that remains responsible for huge economic losses to both the baking industry and the consumers [4, 5, 3]

When gelatinized, starch is cooled down to ambient or sub-ambient temperature and it undergoes a partial crystallization which is usually referred to as retrogradation [2] Retrogradation is technologically important where it contributes to significant changes in the mechanical characteristics of the crumb and affects its sensory acceptability as well [6]. Many studies have reported the mechanisms by which structural alterations in starch can be changed to reduce staling of baked products using specific ingredients, such as shortenings and emulsifiers that can delay the retrogradation of starch contents [4, 7, 8]. In addition, it is known that loaves made with shortenings have significant differences in terms of their volume and tenderness of texture as compared those without them [9].

Numerous changes in the internal and external characteristics of the finished product have been reported when shortening is applied in yeast-raised products [10]. The changes that occur in the bread samples during storage have been attributed by a number of factors including amylopectin recrystallization, moisture redistribution, alterations in gluten functionality and the state of the amorphous phase [11]. However, crumb firming is the simplest way to determine bread staling as it indicates a good correlation with sensorial evaluations [3].

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Meanwhile, the thermal analysis, which is based on differential scanning calorimetry (DSC), has been extensively used by several researchers to study starch retrogradation and bread staling [12, 4, 5, 13]. In particular, DSC has been proven to be the most useful instrument in providing basic information on starch retrogradation [4, 13]. It monitors alterations in both the physical or chemical characteristics of a substance as a function of temperature by detecting the heat changes that are associated with such processes [11]. DSC can be used to measure enthalpy which is associated with amylopectin recrystallization as it provides a way of checking the progressive magnitude of staling endotherm [1]. Thus, the aim of this study was to determine the textural and thermal properties of white bread that was made using shortenings of different formulation during storage.

MATERIALS AND METHODS

Materials: Samples of RBD palm oil and RBD palm stearin, with IV of 52.3 and 31.2, respectively, were purchased from a local refinery located in Selangor, Malaysia. Meanwhile, emulsifiers of diacetyl tartaric acid ester of mono-diglycerides (DATEM) and distilled monoglyceride (DMG), with IV of 40 and 105 respectively, were purchased from Danisco Malaysia Sdn. Bhd. a company which is based in Penang, Malaysia. All the chemicals and solvents used were of analytical or HPLC grade.

The Preparation of Shortenings: RBD palm oil and RBD palm stearin were blended in their respective proportions of 100:0, 80:20, 60:40, 50:50, 40:60, 20:80 and 0:100 (w/w). Each blend was added with 6.25% of DMG and 6.25% of DATEM. Shortenings were prepared after complete melting of the oils at 70°C using magnetic stirring and the shortenings obtained were then stored at room temperature (28°C).

Triacylglycerols (TAG) Composition: The TAG composition was determined using a high-performance liquid chromatography system (JASCO PU-1580) that was equipped with a commercially packed RP-18 column (25cm×4.6mm; Merck, Darmstadt, Germany), injector, Jasco RI-1530 detector and Borwin software. The mobile phase was a mixture of acetone-acetonitrile at a ratio of 70:30 (v/v) and at a flow rate of 1 mL/min [14]. The TAG peaks were identified by comparing the retention times of the TAG standards and those derived in the work of Chen *et al.* [15], Marikkar *et al.* [16], as well as Tan and Che Man [17]. Each sample was chromatographed three times and the data were reported as percent areas.

The Preparation and Baking of Dough: A straight dough process was carried out for the preparation of the bread samples using the formulation given in Table 1 below. In total, seven main steps were involved in the breadmaking process; these are mixing, dividing, intermediate proofing, moulding, final proofing, baking and cooling [18]. The ingredients were then combined in a mixer (Kenwood Chef, KMC500) and mixed for 4 min at a low speed and later for 6 min at a high speed. The whole dough was allowed to rest for 5 min after mixing. After resting, the dough was divided into 250g pieces and manually formed into round balls. The dough was placed into greased baking pans with a dimension of 32cm × 18.5cm × 10cm and sent for proofing for two hours. After proofing, the dough samples were baked at 210°C for 14 minutes in an electronic oven (SALVA Modular Deck Oven). After baking, the bread samples were immediately removed from the baking pans and placed on the wire rank to let them cool for approximately one hour at ambient temperature before further analyses.

Colour Measurements: Crumb and crust colour of the bread samples were measured using the spectrophotometer (UltraScan PRO) with D65 standard illuminant, angle of 10° and software EasyMatchQC. Four loaves of each sample were used to evaluate the colour. Bread was sliced into slices with 25mm thickness using a sharp bread knife. The results were recorded using the International Commission on Illumination (CIE) colour values L* (lightness), a* (redness) and b* (yellowness) [19-21]. Each measurement was conducted in three replicates.

Determination of Firmness: After 12 hours of baking, crumb firmness was determined using a texture analyzer (Stable Micro System Ltd. Surrey, England, UK) equipped with a 36mm radius cylinder probe (P/36) according to the AACC standard method 74-09 (2000). The operating conditions were load cell (5 kg), pre-test speed (1.0mm/s), test speed (1.7mm/s) and post-test speed (10.0mm/s). Two slices of bread (25mm thick) were stacked on top of each other. A 25% compression of 6.25mm compression distance was taken. Staling was studied by measuring firmness over a storage period of three days.

Table 1: The basic formulations used in bread-making

Ingredients	Baker's %
Wheat flour	100
Shortening	4
Water	55
Salt	1.5
Sugar (sucrose)	4
Dry instant yeast	1.8

Differential Scanning Calorimetry (DSC): In this study, the differential scanning calorimetry (DSC) measurements were carried out using the Mettler-Toledo DSC 823E1400 model. In particular, nitrogen was used as the purge gas. The samples of 6 mg were loaded to the middle of the aluminium pans using a small spatula before they were hermetically sealed. In addition, indium was used to calibrate the instrument and an empty covered pan was used as a reference. The bread crumb samples were heated from 27 to 200°C at 10°C/min and the parameters measured were the onset temperature (°C), the peak temperature (°C) and the endset temperature (°C).

Statistical Analysis: Meanwhile, the means and standard deviations (SD) were calculated using the MINITAB (version 14.0, Minitab Inc.) statistical software. The MINITAB was used to perform the one-way analysis of variance (ANOVA) and Tukey's family error rate test at the 95% confidence level ($P<0.05$).

RESULTS AND DISCUSSION

Triacylglycerols(TAG) Composition: The triacylglycerols (TAG) structure of fat is an important parameter in the development of food products, such as shortening, confectionary and margarine. They constitute the major components of TAG, but with small proportions of di- and mono-glycerides. In particular, TAGs appear as different crystal structures because they have long hydrocarbon chains that can be packed into different crystal lattices which cause polymorphism [22].

Table 2 shows the TAG profile of different types of RBD palm oil/palm stearin shortenings. The identification of the TAG peaks of the shortenings is based on the TAG standards, as well as according to Chen *et al.* [10], Marikkar *et al.* [16], Tan and Che Man [17]. In total, fourteen TAGs were detected in the RBD palm oil, palm stearin-based shortenings, namely 1: MMM, 2: PLL, 3: MPL, 4: OOL, 5: PLO, 6: PPL, 7: OOO, 8: OOP, 9: PPO, 10: PPP, 11: OOS, 12: POS, 13: PPS, 14: SOS, whereby M, L, O, P and S represent myristic, linoleic, oleic, palmitic and stearic, respectively. Meanwhile, increasing the concentration of palm stearin in the shortenings was found to decrease TAGs, such as OOO, OOP and OOS but it increased PPO and vice versa. However, the TAGs containing oleic and palmitic acids, such as OOP and PPO, were observed to be the dominant TAGs present.

Colour Measurements: Colour is one of the most important indicators of bread quality, as it contributes to consumers' preference [19, 23]. Chemical reactions, which cause browning colour, include the Maillard reactions and caramelization [19-21,24]. Meanwhile, the Maillard reaction is said to occur when most food, such as bread, is heated [24]. The colour of the bread crust and the crumb samples that were made from the different types of shortenings as well as the bread made without shortening are reported in Table 3 below.

Yi *et al.* [23] stated that the most desirable crust and crumb colours of bread samples should be golden brown and creamy white, respectively. The mean L* values of the bread were found to range from 55.45±2.95 to

Table 2: Triacylglycerol profile (% peak area) of different types of RBD palm oil/palm stearin-based shortenings

TAG	Control	80:20	60:40	50:50	40:60	20:80	0:100
MMM	0.53±0.0^{a}	0.62±0.01^{b}	0.65±0.05^{c}	0.54±0.025^{abc}	0.61±0.02^{bc}	0.64±0.00^{bc}	1.03±0.04^{b}
PLL	1.48±0.08^{a}	2.28±0.03^{ac}	1.84±0.45^{bcd}	2.06±0.12^{d}	2.05±0.019^{de}	1.89±0.05^{def}	1.70±0.15^{ac}
MPL	0.39±0.06^{a}	0.27±0.02^{a}	0.33±0.01^{a}	0.32±0.056^{a}	0.32±0.02^{a}	0.23±0.09^{a}	0.32±0.25^{a}
OOL	1.73±0.01^{a}	1.76±0.05^{a}	1.65±0.08^{a}	1.54±0.03^{b}	1.54±0.05^{b}	1.53±0.03^{b}	1.50±0.11^{b}
PLO	11.0±0.37^{a}	10.4±0.26^{a}	9.89±0.53^{ab}	9.21±0.11^{b}	9.03±0.22^{bc}	8.70±0.03^{c}	7.39±0.46^{d}
PPL	8.04±0.21^{a}	11.0±0.04^{b}	9.37±1.68^{a}	10.68±0.11^{b}	10.89±0.12^{b}	9.77±2.02^{a}	10.7±0.41^{b}
OOO	3.86±0.03^{a}	3.66±0.14^{ab}	3.39±0.14^{b}	3.19±0.08^{b}	3.12±0.05^{b}	3.01±0.17^{b}	2.56±0.06^{c}
OOP	25.7±0.07^{a}	22.9±0.45^{b}	21.6±1.01^{bc}	20.41±0.53^{c}	19.80±0.28^{c}	19.29±0.93^{c}	16.5±0.70^{d}
PPO	32.2±0.17^{a}	32.4±0.74^{ab}	34.21±1.20^{ab}	34.31±0.34^{b}	36.65±0.45^{c}	39.8±1.75^{cd}	40.8±0.98d
PPP	5.61±0.25^{a}	5.79±1.50^{ab}	7.57±1.17^{ab}	8.42±1.16^{b}	6.44±1.08^{ab}	5.11±0.63^{ab}	7.66±1.86^{ab}
OOS	2.37±0.13^{a}	1.95±0.08^{b}	1.93±0.16^{bc}	1.79±0.03^{bc}	1.71±0.01^{c}	1.60±0.04^{c}	1.39±0.07^{d}
POS	5.4±0.17^{ab}	5.24±0.04^{a}	5.50±0.29^{a}	5.39±0.0^{ac}	5.76±0.08^{b}	6.43±0.21^{d}	6.11±0.41^{cd}
PPS	1.07±0.08^{a}	1.18±0.26^{ac}	1.55±0.19^{b}	1.63±0.31^{b}	1.55±0.16^{b}	1.47±0.27^{ab}	1.82±0.31^{bc}
SOS	0.54±0.02^{a}	0.50±0.03^{a}	0.50±0.04^{a}	0.51±0.01^{a}	0.51±0.01^{a}	0.50±0.05^{a}	0.53±0.02^{a}

a values are means ± SD; Means with the same letter within each row are not significantly different (n= 3, $p<0.05$).

Abbreviations: TAG, triacylglycerol; M= myristic; L= linoleic; O= oleic; P= palmitic and S= stearic.

Table 3: The colour values of the white bread made using shortenings of different formulations

	L*		a*		b*	
Bread type	Crust	Crumb	Crust	Crumb	Crust	Crumb
control	58.61 ± 3.46^{ab}	76.91 ± 1.38^{a}	12.15 ± 0.95^{ab}	0.99 ± 0.17^{ad}	24.20 ± 1.41^{abc}	13.81 ± 0.79^{abc}
80:20	58.28 ± 2.24^{a}	75.98 ± 3.51^{a}	11.98 ± 1.06^{ab}	0.61 ± 0.05^{b}	24.24 ± 1.26^{abc}	13.18 ± 0.88^{ab}
60:40	57.84 ± 3.47^{a}	77.64 ± 2.73^{a}	11.78 ± 1.30^{ab}	0.60 ± 0.08^{bc}	23.58 ± 2.33^{abc}	13.04 ± 1.08^{ab}
50:50	55.45 ± 2.95^{a}	76.18 ± 2.92^{a}	13.35 ± 0.62^{b}	0.48 ± 0.05^{c}	22.88 ± 1.39^{b}	13.11 ± 0.64^{a}
40:60	56.38 ± 4.04^{a}	76.58 ± 2.00^{a}	12.90 ± 0.90^{ab}	0.85 ± 0.09^{a}	23.24 ± 1.51^{ab}	13.83 ± 0.42^{abc}
20:80	55.96 ± 1.33^{a}	76.99 ± 0.69^{a}	12.91 ± 1.06^{ab}	0.91 ± 0.13^{ad}	23.22 ± 1.25^{ab}	14.15 ± 0.27^{bc}
0:100	61.34 ± 4.84^{a}	77.34 ± 2.13^{a}	12.24 ± 0.43^{a}	1.08 ± 0.12^{de}	25.06 ± 0.83^{c}	14.30 ± 0.57^{bc}
W.SH	64.86 ± 4.60^{b}	75.18 ± 1.40^{a}	$11.86\pm1.01_{a}$	1.38 ± 0.24^{e}	25.49 ± 1.61^{ac}	14.55 ± 0.51^{c}

[a] within a column, the same letters are not significantly different (p<0.05).

W.SH: without shortening

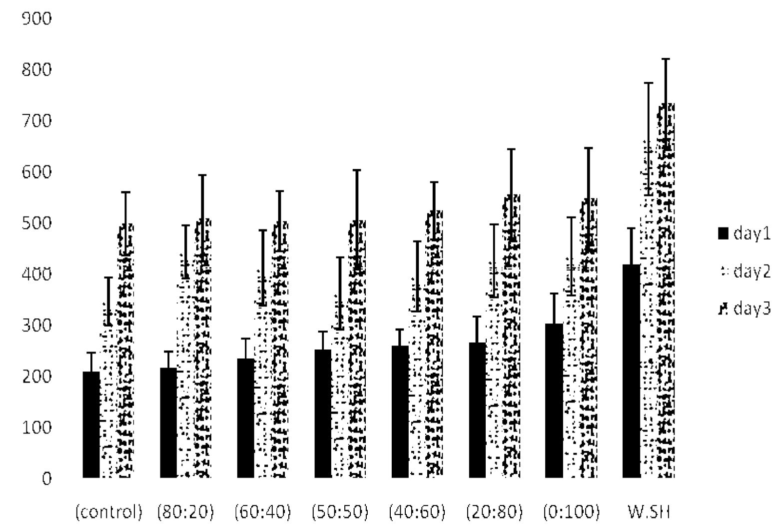

Fig. 1: The effects of different shortening types on the crumb firmness of white bread during storage at ambient room temperature. W.SH: without shortening

64.86±4.60 and from 75.18±1.40 to 77.64±2.73 for the bread crust and crumb, respectively. In more specific, the bread crusts made without the use of any shortening were lighter in colour as compared to those with shortenings, while the ones made from shortening containing 50:50 of the PO:PS ratio had the darkest colour.

The *a** values, which are indications of the red colour in bread, for both bread crumb and crust are shown in Table 3. Bread made from the shortening (type 50:50) was found to have the highest *a** values for crust and the lowest *a** values for crumb. In general, bread that was made from shortening type 50:50 was significantly different ($P<0.05$) from those made with the use of shortening type 0:100, as well as the bread made without shortening. Meanwhile, the highest and lowest *a** values for the crust were associated with the bread that was made from the shortening types 60:40 and 50:50, respectively. The highest and lowest *a** values for the crumb were related to the bread that was made from the shortening type 50:50 and the one that was made without the use of any shortening. Nonetheless, the *b** values, which indicate yellow, did not show any significant difference *($P<0.05$)* between the bread types, except for the bread that was made from shortening type 50:50 and those without any shortening. It is important to highlight that the effects of shortening type 50:50 on the crust and crumb colours of the white bread samples were more obvious than the other shortening types.

Determination of Firmness: Hathorn *et al.* [25] stated that bakers measure their bread texture to consistently and objectively monitor it, while maintaining their own concept of quality at the same time. It is crucial to note that bread firmness is one of the measurements of the degree of staling, along with other attributes. Figure 1 shows the crumb firmness for the bread that was made using different types of RBD palm oil/palm stearin-based shortenings. The bread that was made without using any

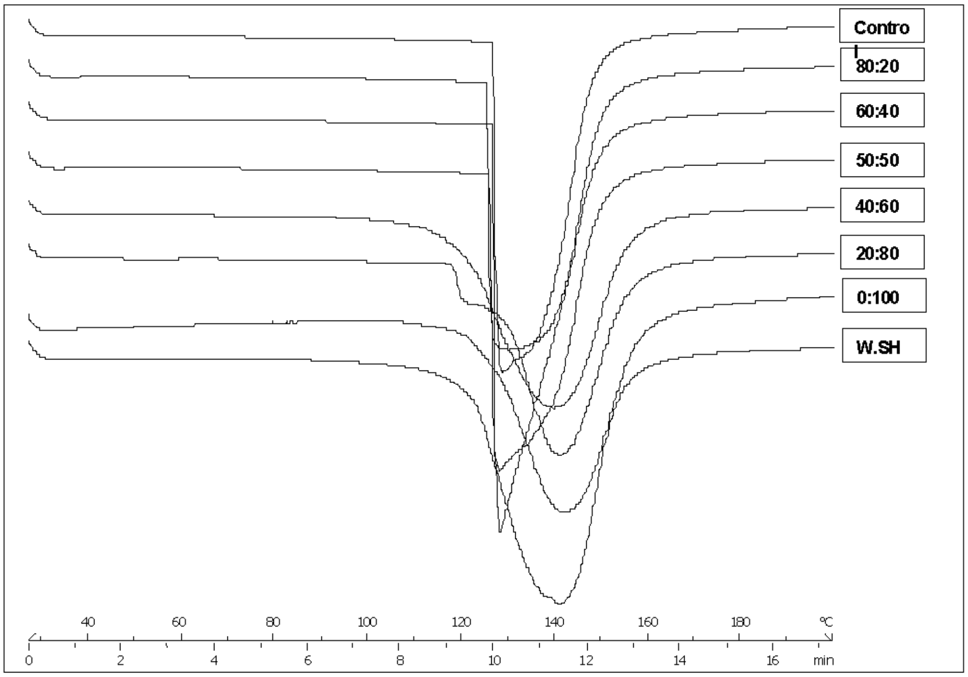

Fig. 2: The thermograms of the bread samples made using different shortening formulations during storage (Day 1) W.SH: without shortening

shortening was used as a comparison for those made using shortening, while the bread made with shortening containing 100% palm oil was used as a control. The firmness was measured daily for a period of 3 days.

In this study, a distinct change was found in the crumb firmness of all the bread that was observed over the storage period examined. For example, the bread firmness was shown to range from 209.2 to 419.7g for Day 1 and this was from 346.6 to 664.2g on Day 2. In particular, the bread that was made without using any shortening was observed to possess a significant difference ($p<0.05$) with those made with the addition of shortenings. On Day 3, the firmness ranged from 498.9 to 734.4g and after three days of storage, the bread that was made from the shortening type (100:0) was shown to have the lowest firmness as compared to the highest firmness shown by those that were made without using any shortening.

These results are in good agreement with those by Roach and Hoseney [26], who found that the bread containing shortening had lower firmness than those that were made without using any shortening. In the same vein, Aini and Maimon [27] reported that the highest level of palm stearin in the shortening formulation, the firmer the bread texture would become. In general, the crumb firmness evaluation during the storage period of three days indicated the important effects of shortening on the shelf life of bread. The effect is related to the inhibition of shortenings on the retrogradation of starch which has been observed to delay the staling of bread by decreasing the firmness of bread crumb, as reported by Chin *et al.* [18].

Differential Scanning Calorimetry (DSC): Bread staling occurs when bread looses its freshness and when crumb hardness increases. This could lead to the loss of consumer acceptance. During storage, the crystalline structure of the starch in bread is slowly recovered at the short range scale. This process is commonly known as retrogradation [6]. The retrogradation of starch in bread can easily be followed by the DSC analysis, which is used to detect the changes in the heat that is associated with such process [11]. On the contrary, Sahlström and Bråthen [13] reported that the changes in the crystallinity of starch, as measured by DSC did not correlate well with the changes in staling, which was measured as crumb firmness.

In this study, the thermal properties of white bread made with or without shortening were determined on the first, third and seventh days of storage, as shown in Figures 2, 3 and 4, respectively. The DSC analysis of the crumb characteristics of the bread samples clearly showed one endothermic peak.

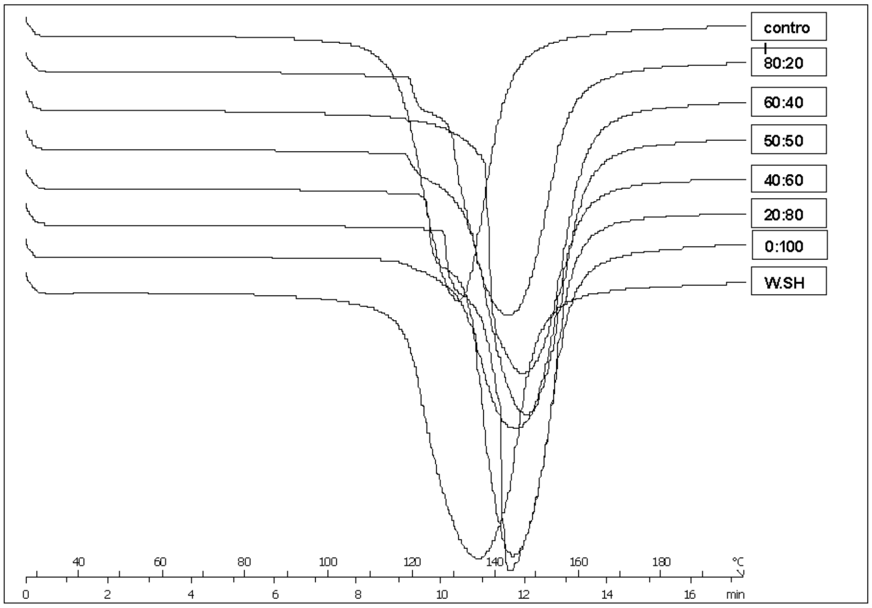

Fig. 3: The thermograms of the bread samples made using different shortening formulations during storage (Day 3). W.SH: without shortening

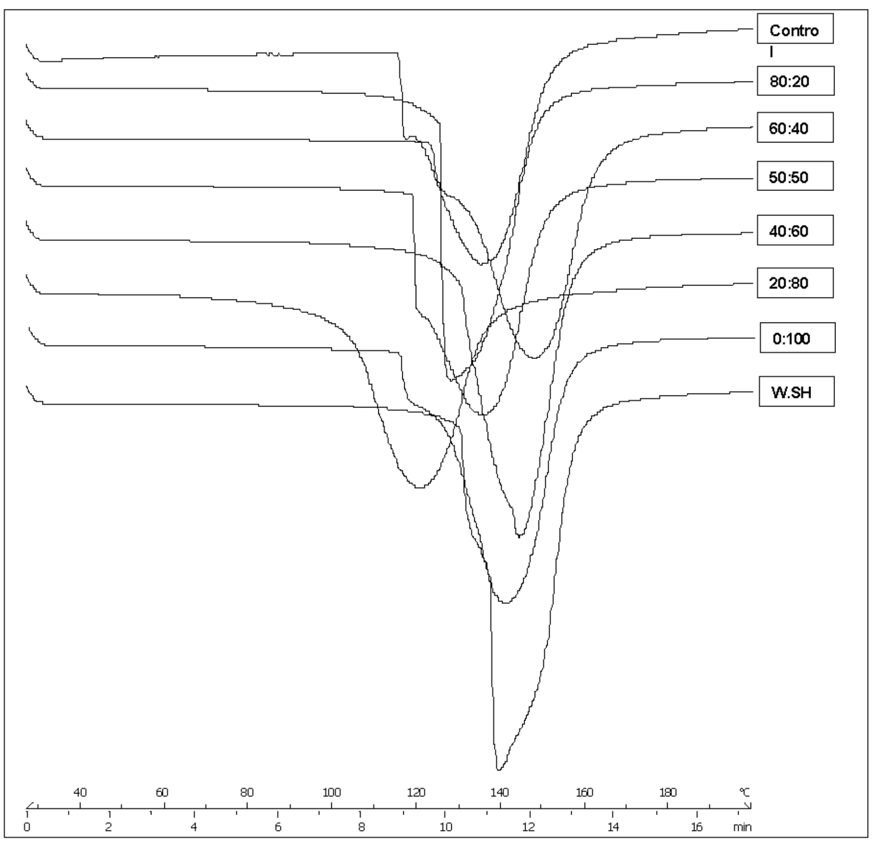

Fig. 4: The thermograms of the bread samples made from different shortening formulations during storage (Day 7). W.SH: without shortening

Table 4: A comparison of the DSC data obtained from the heating thermograms of the bread samples

	Onset (°C)			Peak (°C)			Enset (°C)		
Bread samples	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7
Control	126.67	116.29	123.39	127.12	129.58	134.32	147.91	142.98	151.27
80:20	125.20	127.29	125.15	128.6	141.46	126.57	149.72	157.90	148.41
60:40	126.23	136.84	123.41	126.53	145.17	146.68	149.17	161.88	162.25
50:50	125.89	130.70	118.80	126.64	146.00	134.69	149.54	161.69	150.29
40:60	119.35	123.15	129.41	139.00	143.47	142.96	155.53	159.49	156.80
20:80	118.13	138.75	103.22	140.31	141.60	119.77	155.80	158.31	135.91
0:100	124.50	132.96	115.13	141.25	142.06	139.18	158.09	158.23	154.86
W.SH	120.69	117.59	135.62	139.71	134.54	137.61	153.58	150.01	156.84

W.SH: without shortening

The bread crumb samples with different aging times were analyzed and the starch was completely gelatinized as measured by the DSC. For this, the bread crumb thermograms showed a single peak and the onset temperature which ranged from 118.13 to 126.67, 116.29 to 138.75 and 103.22 to 135.62 for the 1st day, 3rd and 7th days, respectively (Table 4). As previously reported by Davidou *et al.* [12], this single peak was due to the dissociation of amylose-lipid complexes. However, the absence of other peaks was resulted from the fact that the starch in the crumb had completely been gelatinized during baking.

CONCLUSIONS

Both the thermal and textural characteristics of bread baked using different shortening formulations were determined in the present study. The values of the crumb firmness during storage were found to reduce when shortenings were added to white bread. Among the shortenings, the crumb firmness was found to increase with the increase in the palm stearin content in the shortening formulations. Based on the results gathered from the texture analyzer, the bread samples that were made without the addition of any shortening showed the greatest staling. Meanwhile, the best properties for reducing bread staling was shown by the bread sample that was added with 100:00 of PO:PS, i.e. the one which was used as the control. The crumb thermograms indicated a single peak, which was attributed by the dissociation of amylose-lipid complexes. However, no correlation was found between the DSC measurements on the changes in staling with crumb firmness.

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