Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2021 18(SI-2): 369-379. **OPEN ACCESS**

Palm shortening to replace chicken fat in cooked reformed chicken meat

W. A. Fahmi Wan Mohamad[1]*, Nur Adila Basari[1,2], Che Abdullah Abu Bakar[1], Noor Lida Habi Mat Dian [2], Miskandar Mat Sahri[2]

[1]School of Food Industry, Faculty of Bioresource and Food Industry, Universiti Sultan Zainal Abidin, 22200 Terengganu, **Malaysia**
[2]Department of Chemical and Food Technology, Politeknik Tun Syed Nasir Syed Ismail, 84600 Pagoh, Johor. **Malaysia**
[3]Malaysian Palm Oil Berhad (MPOB), 43000 Kajang, Selangor. **Malaysia**

***Correspondence:** fahmimohamad@unisza.edu.my **Received 05-07-2021, Revised: 12-08-2021, Accepted: 15-08-2021 e-Published: 21-08-2021**

High level of animal fat content in meat products has raised a quality issue on the rancidity development of the products during storage. The animal fat also contributes to the high calorie content in the products, which is unhealthy for the consumers. Therefore in this study, the potential of replacing the animal fat in cooked reformed chicken meat product with palm shortening was explored. The palm shortening contained varied amounts of palm olein (POo), palm kernel oil (PKO), palm stearin (POs) and/or red palm olein (RPOo), which were formulated to achieve slip melting point similar to that of chicken fat. Oxidative rancidity of the meat samples was also measured from their concentrations of thiobarbituric acid reactive substances (TBARs) throughout 60-day storage at 0±4^{o}C. It was found that the meat with chicken fat had the highest TBARs values till the end of storage period. On Day 30, the TBARs values of the batter formulated with chicken fat and palm shortening without RPOo were 3.32 and 2.42 mg malonaldehyde (MDA)/kg respectively. Addition of 22.5% and 45% of RPOo in the palm shortening reduced the TBARs values to 1.84 mg MDA/kg and 1.57 mg MDA/kg respectively. Therefore the use of palm shortening in the cooked reformed chicken meat product is promising in lowering lipid oxidation especially when incorporating RPOo.

Keywords: Rancidity, chicken meat, TBARs, palm shortening, red palm olein

INTRODUCTION

Chicken farming industry is one of the most commercialized and integrated in its production system compared to other livestock-subsector in Malaysia. In the year 2012 to 2016, poultry meat had recorded the highest level of self-sufficiency ratio (SSR) with the value of 98% compared to pork with 92.6% (Department of Statistic Malaysia, 2017). The nutritional quality of chicken meat is one of the major factors for consumers to choose the meat besides their affordable price according to Foreign Agricultural Services (FAS) in 2001. The high demand of chicken meat consumption has been overcome by producing a new healthy chicken meat product with low fat content and extended shelf life. Food scientists have developed varieties of restructured meat products, which are ready-to-eat, easily available, healthy and tasty (Gadekar et al. 2015).

The introduction of restructured or reformed meat has resulted in a lot of benefits of these products to the consumers. The restructuring process will reformulate a new product and control serving size of the product, reduce cooking shrinkage, provide a better cost accounting and increase the possibility to create new products for

different markets. Restructured meat products can be developed according to the requirements of the consumers who desire for a low fat, low salt and high dietary fibre with the presence of antioxidants in meat products. The functionality and acceptability of restructured chicken meat has been improved by the application of various sources of binders and extenders (Gadekar et al. 2015). The examples of reformed chicken meat product available in the market are nuggets and meat patty.

High level of animal fat in the product will increase the amount of unsaturated fatty acids, which are susceptible to lipid oxidation in the product. The presence of chicken fat in the product has developed a quality issue on the rancidity development of product during storage (Ismail and Joo, 2017). Furthermore, high content of animal fats in the meat products also contributes to the increasing calorie content which is unhealthy for the consumers (Ismail *et al.* 2020). Many studies have been conducted on the replacement of palm fat in the meat product with different objectives. They studied the replacement effects on emulsion stability, nutritional content, physicochemical characteristics and sensory quality of the products (Youssef and Barbut, 2011; Oguntibeju et al. 2009; Tan et al. 2006; Wan Rosli et al. 2010).

Wan Rosli (2006) suggested that the use of palm oil as an ingredient in meat products will generate better quality processed meat products in the market. Babji et al. (2001) demonstrated that the substitution of chicken fat with red palm olein in the chicken frankfurter improved the nutritional properties and vitamin E content of the product. Palm oil is one of the richest sources of fat-soluble antioxidants such as carotenes, tocopherols and tocotrienols. The crude oil extracted from palm fruit through a patented process is rich in phenolic antioxidants such as flavonoids, polyphenols and phenolic acids, water-soluble vitamins and organic acids. Red palm olein (RPOo) is the premium product of palm oil, which contains the highest level of natural carotenoids and vitamin E.

In this study, the potential of replacing chicken fat with palm shortening in the formulation of reformed and cooked chicken meat product was explored. Lipid oxidation was compared between the meat products using the thiobarbituric acid reactive substances (TBARs) method to evaluate the oxidative stability contributed by the different fat sources used throughout 60-day storage at 0±4^{o}C.

MATERIALS AND METHODS

Materials

Fresh whole chicken legs were purchased from TD Poultry Sdn. Bhd. (Kuala Terengganu, Terengganu, Malaysia). The fresh chicken legs were manually deboned to separate the meat and skin. The lean meat and the skin were separately packed in high density polyethylene (HDPE) bags and kept in a refrigerator for not more than 24 hours at 1±4 ^{o}C prior to further processing.

Palm Olein, PKO and POs (iodine value, IV = 35.7) were supplied by Cargill Fats and Oils Specialty Company. Red Palm Olein (RPOo) was supplied by Jomalina Sdn. Bhd. (Klang, Selangor). The oils were kept in the cold room at -10 ^{o}C until being used.

Samples preparation

The chicken meat batter was stuffed and cooked in polyethylene tubes to determine the development of fat oxidation in a model system. A total of four formulations of meat batter were prepared. The control batter consisted of chicken meat and chicken fat without any addition of blended palm shortening. The other three formulations contained different blended palm shortening comprising various amounts of palm olein (POo), palm kernel oil (PKO), palm stearin (POs) with IV of 35.7, and red palm olein (RPOo). The different formulations are shown in Table 1.

Table 1: Composition of blended shortening

Formulation	POo (%)	POs (%)	PKO (%)	RPOo (%)
I	65	30	5	0
II	41.5	31	5	22.5
III	18	32	5	45

POo = Palm olein, POs = Palm stearin, PKO = Palm kernel oil, RPOo = Red palm olein.

A batch size of 5 kg palm shortening was prepared for each formulation. The percentages of POo, POs, PKO and RPOo in each formulation were adjusted to produce blended palm shortening with melting point similar to chicken fat. The combinations of different levels of RPOo were determined according to full factorial design by using Design Expert 6.0 software.

Preparation of palm shortening

In preparation for the blending process, the POo, PKO and POs were heated in the oven for 12 hours at 60 ^{o}C to melt. RPOo was similarly melted but at 40 ^{o}C. The POo, PKO and POs

were blended together by manual stirring. The blended oil was briefly heated in a microwave oven (brand: Panasonic NNST342) set at high power for one minute. Then, the emulsifier (Dimodan® Distilled Monoglycerides) were added into the mixture and stirred to dissolve. Finally, the required amounts of RPOo were added at the end of the blending process to reduce the chances of carotene lost when the temperature of the blended oil is high (Wan Mohamad et al. 2017).

The blended oil was mixed using a stirrer (RW20 digital overhead stirrer) in a stainless steel container at the temperature of 1±2 °C. The temperature was controlled using a water bath (brand: Memmert) in the presence of ice cubes. The mixture was stirred continuously at medium speed setting for 15 to 20 minutes depending on the blending formulation until a semisolid liquid was formed. The formulation with 45% of RPOo required longer blending time compared to other formulations because of the olein characteristic of RPOo. The blended palm shortenings were kept in an airtight plastic container and stored at the temperature of 10 °C for storage.

Preparation of pre-emulsion

Pre-emulsion was prepared according to the method prepared by Savic (1985) to facilitate the addition of fat during batter preparation and to prevent fat separation during cooking. For this experiment, 1,000 g of 4 different batches of pre-emulsion were prepared. The pre-emulsion consisted of chicken fat or blended palm shortening, isolated soy protein (ISP) and water at the ratio of 7:1:7. A food blender (brand: Philips 600W) was used to mix the three ingredients. Initially, hot water (temperature: 65-70 °C) was mixed with ISP at medium speed setting for 3 to 4 minutes until a smooth and shiny gel was formed. Then, chicken fat or palm shortening was added and the mixing was continued for another 5 minutes at high speed to form a smooth and uniform emulsion. The pre-emulsion was kept at 0-4 °C while the meat batter was being prepared.

Preparation of meat batter

The meat batter was prepared according to the method described by Barbut (1997) with slight modifications. Four formulations of chicken meat batter were prepared with each formulation containing 72% chicken meat and 1.5% sodium chloride. The control formulation contained 26.5% chicken skin (fat) and the other four formulations contained 26.5% of palm shortening with various amounts of POo, PKO, POs and RPOo as shown in Table 1. The percentages of chicken meat and fat in the meat batter were in accordance with the Malaysia Food Regulation 1985 which requires not less than 65% of meat and not more than 30% of fat content in a meat product. The experimental design showing the source of fat in each formulation for this experiment is shown in Table 2. The experiment was done in triplicates.

Table 2: Composition of blended shortening

Meat batter sample	Source of fat*
A	Chicken fat (control)
B	I
C	II
D	III

*Refef Table 1 for the composition of shortening.

Frozen chicken meats were thawed overnight in a refrigerator at the temperature of 4±1 °C and cut into approximately 1 cm^2. Exactly 1,940 g of chicken meat was mixed in a stainless steel bowl with 4 g of sodium chloride at high speed setting for 30 s using a mixer (brand: Philips HR 1456, 175W). The meat was allowed to rest for 30 s and then 720 g of the pre-emulsion was mixed with the meat and mixing process continued for 3 minutes. All steps during mixing process were done under controlled temperature by placing the mixing bowl in an ice-water bath and final temperature of meat batter did not exceed 6 °C. 45 g of the meat batter was manually stuffed separately into 50 ml polypropylene tubes and centrifuged (centrifuge brand: Sigma 3-16K, Sartorius) at the speed of 3000 rpm at 10 °C for 1 minute to compress the meat batter in the polypropylene tube and remove air spaces existed within the batter.

After centrifugation, the tubes containing the batter were heated for about 20 minutes by placing the tubes in a water bath set at temperature 95 °C until the core temperature of the batter reached 75 °C. A thermometer (brand: Fluke 51-1) was used to measure the core temperature of the batter. A thermocouple was inserted vertically into the batter to monitor the temperature at the centre of the batter. The tubes were removed from the hot water bath and transferred into an ice water bath for approximately 30 minutes until the core temperature reached 5 °C. All tubes containing the cooked batter were kept at the chilling temperature of 0±4 °C for an accelerated storage study. The analyses were conducted at 0, 15, 30, 45 and 60 days of storage time. Altogether, three

tubes were prepared for each storage time, thus altogether 15 tubes of meat batter were prepared.

Analysis of palm plein (POo), palm stearin (POs), palm kernel oil (PKO), red palm olein (RPOo) and blended palm oil

Determination of slip melting point (SMP)

Determination of slip melting point (SMP) was conducted according to Malaysian Palm Oil Board (MPOB) Test Method p4.2: 2004. SMP is the temperature at which a column of fat, of specified length, rises in an open capillary tube under the specified condition of test. This analysis was conducted to determine the SMP of POo, POs (IV = 35.7), PKO, RPOo, and blended palm oil. All samples were melted and filtered through a filter paper. The filtration process was conducted in an oven at 60^{o}C to avoid any crystallization of the sample. The samples were left in the oven for 10 minutes till they were free of air bubbles.

Three clean capillary tubes were dipped into the completely liquid sample to obtain 10 mm high of samples in the column. The fat columns were chilled at once by holding and rolling the ends of the tubes containing samples and pressed against a piece of ice until the fat solidified. The open ends of the tubes were prevented from touching the ice. The tubes were wiped against a piece of tissue paper as quickly as possible. The tubes were placed in a test tube, held in a beaker of water equilibrated at 10±1 ^{o}C in an incubator. The beaker was transferred into the incubator and held for 16 hours at 10±1 ^{o}C. The capillary tubes were removed from the test tubes and attached to a thermometer with the position of the lower ends of the tubes were on the same level with the bottom of the mercury bulb of the thermometer. The thermometer was suspended in a beaker containing 400 ml of boiled distilled water and the lower end of the thermometer was immersed to a depth of 30 mm. The starting temperature of the water bath was adjusted to 8-10 ^{o}C below the expected slip point of the sample. The water bath was agitated with a magnetic stirrer and the heat applied to raise the temperature at the rate of 1 ^{o}C per minute. The increase in temperature was slowed down to 0.5 ^{o}C per minute as the SMP was reached. The heating process was continued until the fat column rose in each tube. The temperature of the water for every fat column was recorded and the average temperature of all tubes was determined. The temperature difference between the three tubes should not be more than 0.3 ^{o}C. The average values of two sets of triplicate results were recorded as the SMP and were expressed to one decimal place.

Determination of fatty acid composition (FAC)

Determination of fatty acid composition (FAC) as their methyl ester was conducted according to Malaysian Palm Oil Board (MPOB) Test Method p3.5: 2004. The FAC measures the weight percentage of the individual fatty acid (as their methyl ester), whether it is present in the palm oil products as a free fatty acid or in its esterified form in the triacylglycerol molecules. The FAC was determined by gas liquid chromatography using a fused silica capillary column (J&W Scientific, Agilent Technologies, Palo Alto, CA, U.S.A) of length 60 m, internal diameter 0.25 mm and film thickness 0.25 µm, at an oven temperature of 185 ^{o}C with the detector temperature at 240 ^{o}C and the injector at 240 ^{o}C. The carrier gas was helium, flowing at the flow rate of 0.8 ml/min.

Determination of solid fat content (SFC)

Determination of solid fat content (SFC) was conducted according to Malaysian Palm Oil Board (MPOB) Test Method p4.8 : 2004. In sample preparation, the samples were melted at 70 ^{o}C and mixed thoroughly. For hard stearins, the melting temperature was 80 ^{o}C. The melted sample was then transferred into a sample tube with the sample being about 3 cm in height (it should not exceed 4cm). Samples were prepared while hot. In this research, measurements were conducted using parallel method; a number of tubes were prepared according to the temperatures of measurement.

Firstly, all samples in the tubes were melted in a water bath set at 70 ^{o}C for 30 minutes. The Pulsed Nuclear Magnetic Resonance instrument was set for measurement as recommended by the manufacturer. Then, three calibration materials of 0%, 31.5% and 75.3% solid were measured respectively. The samples were transferred into a water bath set at 0 ^{o}C and kept for 90 minutes. The sample tubes were transferred in sequence at the same time interval in batches. Each batch was transferred at a selected measuring temperature.

For stabilised parallel procedure used in this study, the sample tubes were kept in the water bath at 26 ^{o}C for 40±0.5 hours, re-chilled at 0 ^{o}C for 90 minutes. At the same time, the water baths were set to the measuring temperatures involved, which were 5 ^{o}C, 10 ^{o}C, 15 ^{o}C, 20 ^{o}C, 25 ^{o}C, 30 ^{o}C, 35 ^{o}C, 40 ^{o}C, 45 ^{o}C, 50 ^{o}C, 55 ^{o}C and 60 ^{o}C. After re-chilling procedure, the chilled sample

tubes were transferred to pre-equilibrated thermostatic bath in sequence at fixed intervals. Same numbers of sample tubes were transferred to each water bath according to the measuring temperatures. After holding at each measuring temperature for 60 minutes, the SFCs (displayed) of all samples were measured directly. Two measurements at each chosen temperature were carried out on test portions taken from the same test sample. The results were expressed as the arithmetic mean of two measurements, provided that the requirement for repeatability was satisfied. The difference between the two measurements should not exceed ±0.74%.

Analysis of thiobarbituric acid reactive substances (TBARs) of meat batter

Lipid oxidation was determined using the thiobarbituric acid reactive substances (TBARs) method designed by Buege and Aust (1978). For the sample preparation, the reformed chicken meat was cut into small pieces and 4±0.1 g of sample, weighed and transferred into a polypropylene tube. It was mixed with 20 ml of thiobarbituric acid (TBA) solution containing 0.37% of 2-thiobarbituric acid (brand: Merck), 15% of trichloroacetic acid (TCA) (≥ 99.0% - ACS Reagent, Brand: Merck) and 0.25N, 37% hydrochloric acid (HCl) (brand: Rendemann Schimidt). The mixture was homogenized for 3 minutes by using a homogenizer (brand: Wiggen Hauser D500; speed: 10000-29000 min^{-1}). After that, the tube was heated in a water bath at temperature 95±1 ^{o}C for 10 minutes to develop pink colour followed with cooling step by placing the tube under running tap water. The tube was then sonicated by using Ultrasonic Cleaner Model UC-10 for 30 minutes. Then the sample was centrifuged at 4200 rpm using Sartorius Bench Top Centrifuge Model for 12 minutes. The supernatant was then filtered by using filter paper (Whatman Grade 1).

The absorbance of clear supernatant was measured at 532 nm using the spectrophotometer (Shimadzu UV- Mini – 1240). The TBARs value of the sample was calculated as malondehyde (MDA) concentration (mg/kg sample), using the equation generated from the standard curve prepared using 1,1,3,3 – tetramethoxypropane (TEP) (brand: Sigma Aldrich). TEP is hydrolised under mild acid condition and produces MDA and ethanol. MDA then reacts with TBA and form the pink colour solution. MDA concentration was calculated using Eqn. 2.1:

MDA concentration = $0.061x + 0.0684$, Eqn 2.1

(mg/kg sample)

where x = Absorbance – blank

Statistical analysis

Data obtained were analysed using One-way Analysis of Variance (ANOVA) with SPSS version 20.0 (SPSS, Chicago, USA). The data were tabulated and significant effects were tested using the Duncan's Multiple range test and significance was established at $p<0.05$.

RESULTS

Slip melting point (SMP) analysis was conducted on the palm oils and blended palm oils as listed in Table 3. Figure 1 shows the percentage of solid fat content (SFC) in the unblended and blended palm oil. Fatty acid composition (FAC) of unblended oil and blended palm oil are shown in Table 4.

Lipid oxidation of the samples was measured using the TBARs assay (milligram MDA/kg sample). Table 5 shows the TBARs values of the four formulations of meat batter that were cooked and stored at 0±4 ^{o}C for 60 days. The control batter (Sample A) consisted of chicken meat and chicken fat only, while the other three formulations, chicken fat was replaced with different blended palm shortening comprising different amounts of palm stearin (POs) with iodine value of 35.7, palm olein (POo), palm kernel oil (PKO) and red palm olein (RPOo). The detailed composition of the blended shortening is shown in Table 1.

DISCUSSION

Slip melting point (SMP) analysis is a method of determining the temperature at which the solid form of the fat melted into liquid form completely or becomes sufficiently fluid to slip or run (AACCI method). Based on Table 3, samples with lower SMP exhibited liquid properties at room temperature compared to those with higher SMP. Table 3 shows that POo, PKO, and RPOo have liquid characteristic with the SMP values of 16.5 ^{o}C, 27.9 ^{o}C and 16.3 ^{o}C respectively while POs was solid at the room temperature with SMP value of 52.6^{o}C. There was no significant difference ($P>0.05$) in the means of SMP of the three blended oils. The range of the SMP was from 39.7±0.07 ^{o}C to 39.9±0.20 ^{o}C, which was within the range of the melting point of chicken fat reported to be in the range of 23 ^{o}C to 40 ^{o}C (Alm, 2013).

Table 3: Slip melting point of palm olein (POo), red palm olein (RPOo), palm kernel oil (PKO), palm stearin (POs) and blended palm oils.

Type of Palm Oil	Slip Melting Point (°C)
POo	16.5±0.00[a]
RPOo	16.3±0.00[a]
PKO	27.9±0.06[b]
POs	52.6±0.10[d]
65% POo+30% POs+5% PKO	39.7±0.07[c]
41.5% POo+31% POs+5% PKO+22.5%RPOo	39.3±0.14[c]
18% POo+32% POs+5% PKO+45% RPOo	39.9±0.20[c]

Means of three determinations ± standard deviation

[a-d] Means with different letters within each column are significantly different (P<0.05)

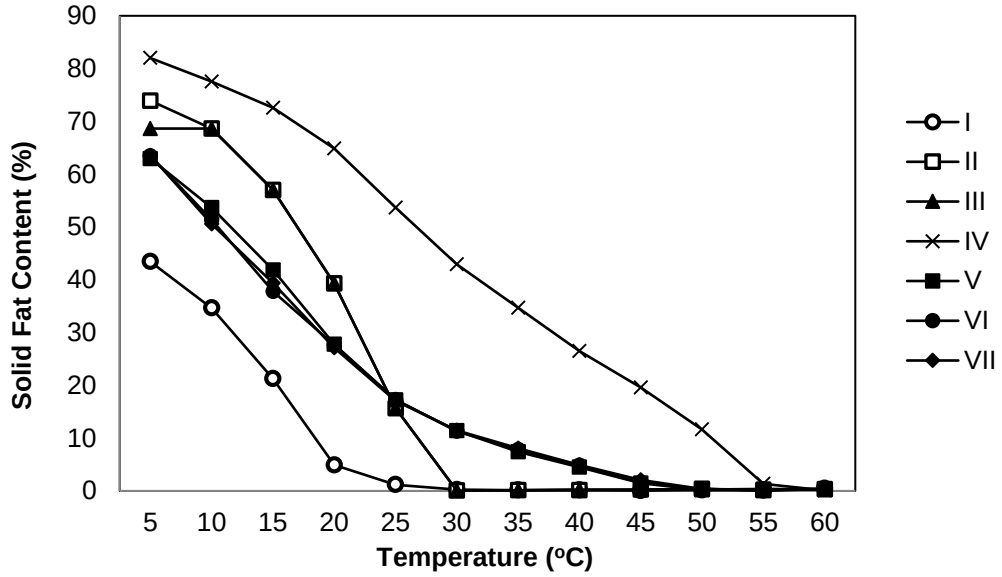

Figure 1: Percentage solid fat content of Fatty acid compositions of palm olein (POo), red palm olein (RPOo), palm kernel oil (PKO), palm stearin (POs) and blended palm oils.
(I – POo, II – RPOo, III – PKO, IV – POS, V – 65% POo+30% POS+5% PKO, VI – 41.5% POo+31% POS+5%PKO+22.5%RPOo, VII – 18% POo+32% POS+5% PKO+45% RPOo)

Table 4: Fatty acid compositions of palm olein (POo), red palm olein (RPOo), palm kernel oil (PKO), palm stearin (POs) and blended palm oils.

Fatty Acid Compositions	Type of Palm Oil						
	I	II	III	IV	V	VI	VII
C6:0	ND	0.0	0.3	ND	ND	ND	ND
C8:0	ND	0.0	4.1	ND	0.2	0.2	0.2
C10:0	ND	0.0	3.5	ND	0.2	0.2	0.2
C12:0	0.3	0.3	47.7	0.1	2.6	2.7	2.7
C14:0	1.1	1.2	15.6	1.3	1.9	2.2	2.3
C16:0	40.3	37.7	8.4	58.5	45.0	44.4	43.9
C16:1	0.2	0.3	ND	0.2	0.2	0.2	0.2
C18:0	3.8	3.7	2.4	4.6	4.5	4.4	4.5
C18:1	43.5	44.4	15.4	28.5	36.5	36.4	36.4
C18:2	10.0	11.7	2.5	6.2	8.1	8.4	8.7
C18:3	0.3	0.4	ND	0.2	0.2	0.2	0.2
C20:0	0.4	0.4	0.1	0.4	0.5	0.4	0.4
Saturated	0.1	0.0	0.0	0.1	0.0	0.1	0.1
Monounsaturated	43.7	44.7	15.4	28.6	36.7	36.6	36.6
Polyunsaturated	10.3	12.1	2.5	6.3	8.3	8.6	9.0
Total	45.9	43.2	82.1	64.9	55.0	54.6	54.3
Iodine Value (calculated)	55.6	59.6	17.6	35.6	46.1	46.5	47.2

I – POo, II – RPOo, III – PKO, IV – POs, V – 65% POo + 30% POs + 5% PKO, VI – 41.5% POo + 31% POs + 5% PKO + 22.5% RPOo, VII – 18% POo + 32% POs + 5% PKO + 45% RPOo, ND – Not detected

Table 5: Thiobarbituric Acid Reactive Substances (TBARs) values of cooked reformed chicken meat batters during storage at 0±4 ºC

Formulation	TBARs (mg MDA/kg sample)				
	Day 0	Day 15	Day 30	Day 45	Day 60
A	$^{r}0.780\pm0.012^{a}$	$^{x}1.830\pm0.004^{b}$	$^{v}3.320\pm0.009^{c}$	$^{u}4.050\pm0.007^{d}$	$^{w}4.910\pm0.020^{e}$
B	$^{p}0.700\pm0.021^{a}$	$^{w}1.490\pm0.008^{b}$	$^{u}2.420\pm0.004^{c}$	$^{t}3.150\pm0.022^{d}$	$^{v}3.530\pm0.005^{e}$
C	$^{p}0.690\pm0.004^{a}$	$^{s}1.030\pm0.002^{b}$	$^{s}1.840\pm0.001^{c}$	$^{q}2.270\pm0.071^{d}$	$^{s}2.850\pm0.003^{e}$
D	$^{p}0.690\pm0.001^{a}$	$^{r}0.970\pm0.017^{b}$	$^{q}1.570\pm0.008^{c}$	$^{p}2.010\pm0.012^{d}$	$^{p}2.460\pm0.021^{e}$

A - chicken fat (control), B - palm fat without RPOo, C – palm fat with 22.5% RPOo, D – palm fat with 45% RPOo, RPOo – Red palm olein

Means of three determinations ± standard deviation

$^{a-e}$ Means with different letters within each row are significantly different (P<0.05)

$^{p-x}$ Means with different letters within each column are significantly different (P<0.05)

Solid fat content (SFC) analysis of blended vegetable oil is an important analysis used in determining the fundamental characteristic of fatty foods. This analysis determines the physical appearance and plasticity of an edible oil product. Based on Figure 1, the percentage change of SFC of POo and RPOo can be seen at the temperature from 5 ^{o}C to 20 ^{o}C. Meanwhile, blended palm oils containing 22.5% and 45% RPOo exhibited the formation of liquid oil at the temperatures from 5 ^{o}C to 30 ^{o}C. PKO had transformed into liquid oil rapidly between the temperatures of 10 ^{o}C to 30 ^{o}C. The result showed that at 5 ^{o}C, POs had the highest percentage of solid fat and POo had the lowest amount of SFC.

Analysis of SFC is important in determining the temperature of the desired percentage of solid fat content to maintain the product consistency, stability and determination of product characteristics. SFC is a complementary analysis in the development of a meat product with the application of palm fat as a chicken fat replacer. In a previous study, Alina (2000) reported that higher values of SFC increased the volume of fat emulsions in palm fat based chicken nuggets. High level of palmitic acid in palm oil gives advantages to the characteristic of palm fat. Higher level of saturated fatty acids (palmitic acid) in palm fat increased the SFC melting characteristic and SMP values (Alina *et al.* 2009). In contrast, chicken fats from chicken skin and lean fat contained lower SFC profiles and SMP values (Alina, 2000). High value of SFC increased the heat stability and reduces the probability of the sample from being oxidized.

Table 4 shows that POo, PKO, POs, RPOo and blended palm oils are high in palmitic acid (C16:0) and oleic acid (C18:1). Palmitic acid (C16:0) are present in the range of 37.7-58.5% while oleic acid (C18:1) are in the range of 28.5-44.4% as these are the major components of fatty acids composition.

The range of fatty acids compositions in all these crude palm oil fractions were based on the main standard of fatty acids compositions in the crude palm oil (CPO). Tan and Man (2000) reported that CPO contained high level of palmitic acid (C16:0), which accounts for approximately 44% of the total fatty acids. The second major fatty acids were oleic acids (C18:1) with the value of 40% of the total fatty acids. Other remaining fatty acids were linoleic acid (C18:2) and stearic acid (C18:0) accounting for 10% and 5%, respectively. The fatty acids profile of CPO is significantly different from PKO, which is made up of 85% saturated fatty acids which is mainly lauric acid. Palm kernel oil (PKO) contains high stearic acid (C18:0) instead of palmitic acid (C16:0) and oleic acid (C16:0). In palm oil, most of the saturated fat is present as palmitic acid (16:0) while monounsaturated fat is consisted of oleic acid (C18:1). RPOo has an ideal composition of unsaturated fatty acid to saturated fatty acid ratio as the saturated fatty acids and unsaturated fatty acids are present in the same levels (Love, 1987).

Comparisons of three major fatty acids which are palmitic acid (C16:0), oleic acid (C18:1), and linoleic acid (C18:2) of POo and POs was conducted based on the specifications given by Malaysian Standard MS815:2007 and MS816:2007. According to the specifications of POo in Malaysian Standard MS816:2007, the range of C16:0, C18:1 and C18:2 for POo were 38.2-42.9, 39.8-43.9 and 10.4-12.7; the compositions of C16:0 and C18:1 of POo used in this research has complied to those ranges with the value of 40.3 for C16:0 and 43.5 for C18:1. The value for C18:2 was 10.0 which was slightly lower than the standard. Based on the specification of POs in Malaysian Standard MS815:2007, the ranges of C16:0, C18:1 and C18:2 for POs were 49.8-68.1, 20.4-34.4 and 5.0-8.9 respectively. The fatty acids values of POs also complied within the standard range with the value of 58.5 for C16:0, and 28.5 for C18:1 and 6.2 for C18:2.

In PKO, the normal range of fatty acids for C16:0, C18:1 and C18:2 were 6.5-8.9, 13.2-16.4, and 2.2-3.4 respectively (Siew and Berger, 1986). Hence, the fatty acids compositions of PKO utilised in this study met the standard range by Palm Oil Research Institute of Malaysia (PORIM) with the value of 8.4, 15.4 and 2.5 for C16:0, C18:1 and C18:2 respectively. According to Gunstone *et al.* (1986) and King and Sibley (1984), the normal range of fatty acid composition of RPO for C16:0, C18:1 and C18:2 was 43.1-46.3, 36.7-40.8 and 9.4-11.9 respectively. However, the data shown in Table 4 for C16:0, C18:1 and C18:2 were respectively 37.7, 44.4, and 11.7 which did not follow the range of standard. The discrepancy of this data could be due to the process of fractionation involved in producing RPOo. Fractionation process increased the amount of unsaturated fractions of RPOo, thus affecting the composition of fatty acids in the oil.

High saturated fat contents will provide semisolid characteristic at room temperature, which is more resistant to lipid oxidation in

comparison to the oil with high percentage of unsaturated fatty acids. Based on the analysis, the blended palm oil composed of higher percentage of palmitic acid (16:0) which is saturated fat compared to RPOo and POo. Thus, the blended palm oils have higher stability for lipid oxidation compared to unblended oils.

The TBARs values of the samples were significantly ($P<0.05$) affected by the source of fat and storage time (Table 5). The TBARs values among the samples increased significantly during the sixty-day storage at 0±4 ^{o}C. The initial TBARs values (Day 0) for the four formulations were in the range of 0.68 to 0.78 mg MDA/kg. The highest value was obtained from the samples containing chicken fat as the source of fat. The results of this study showed that replacing chicken fat with blended palm shortening resulted in significantly lower initial TBARs values of the cooked chicken meat batter indicating that the fat oxidation was reduced. The initial TBARs values of the samples containing palm shortening ranging from 0.68 to 0.70 mg/kg were not significantly ($P> 0.05$) different from each other.

It can be observed that throughout the sixty-day storage period, meat samples containing chicken fat as the main source of fat (Sample A) had the highest TBARs value followed by the samples containing palm shortening consisting of POs, POo and PKO only (without RPOo i.e. Sample B). This trend remained until the end of the storage period. The results indicated that the presence of RPOo significantly ($P<0.05$) reduced fat oxidation of cooked chicken meat batter stored at 0±4 ^{o}C.

Based on a report by Castellini *et al.* (2005) chicken breast meat with TBARs values less than 2.5 mg MDA/kg were more preferred by the taste panellists than the breast meat with higher TBARs values. Similarly, Resconi *et al.* (2011) showed that TBARs values of beef higher than 2.2 mg MDA/kg had highest intensities of rancidity and least intense beef odour and flavour. Campo *et al.* (2006) reported that undesirable high intensity rancid flavour was detected in beef when the TBARs value was more than 2.28 mg MDA/kg. From these previous studies, it can be concluded that a critical TBARs value of ~2.0 mg MDA/kg must not be exceeded to avoid rancid flavour of a meat product.

From this study, the TBARs values of the samples without RPOo exceeded the critical value of 2.0 mg MDA/kg on Day 30, while those with RPOo on Day 45. On Day 60 all the samples exhibited extensive fat oxidation as the TBARS values were above 2.0 mg MDA/kg with the control samples having TBARS values of 4.9 mg MDA/kg. It was observed that addition of 22.5% RPOo exhibited a lesser effect on reduction of fat oxidation compared to that by the samples with 45% RPOo, as the TBARs value of the former was 2.85 mg MDA/kg on Day 60, while the latter was 2.46 mg MDA/kg.

Red palm olein (RPOo) is rich in natural antioxidants mainly tocopherols, tocotrienols and carotenes. Tocopherols and tocotrienols are physiologically active compounds of vitamin E. They acted as excellent antioxidants by protecting the oil itself and the product (Nagenderan *et al.* 2000). According to Haila *et al.* (1996) carotene and vitamin E are good combinations of natural antioxidants as they provide synergistic protection against auto-oxidation and photo-oxidation of unsaturated triglycerides. Alpha, β-carotene and lycopene are the compounds of carotenoids, which exerted their antioxidant activities in reacting as the quenchers of singlet oxygen (Di Mascio *et al.* 1989). In addition, palm carotenoids were suggested by several researches to have potential as inhibitor for individual types of cancer. The effectiveness of carotenoids in restraining cancer disease was possessed by the whole compounds in carotenoids rather than in a single homologue (Nagendran *et al.* 2000).

The results of this study were similar to the findings of other researchers such as Alina *et al.* (2012) and Nurkhuzaiah *et al.* (2015) who evaluated the application of red palm oil (RPO) as a source of fat in chicken sausages and nuggets. They reported that the inclusion of RPO in the chicken nuggets significantly improved the oxidative stability of the chicken meat product throughout the storage study.

CONCLUSION

This study proves that blended palm shortening can effectively replace chicken fat in the reformed and cooked chicken meat product. The proper blending of Poo, POs, PKO and/or RPOo produced palms oil blends with melting point close to that of chicken fat. These blends also depicted high values of solid fat content, which increased the stability of the samples against heat and oxidation. The TBARs values, an indicator of lipid oxidation, were lower for the chicken meat samples formulated with palm shortening compared to the formulation with chicken fat as the main source of fat. The replacement of chicken fat with blended palm shortening containing RPOo further reduced lipid

oxidation rate in the meat samples during storage at 0±4°C. At the levels used in this study, the blended palm shortening containing 45% RPOo reduced fat oxidation more effectively than that of blended palm shortening with 22.5% RPOo. The lowest TBARs value of reformed and cooked chicken meat were recorded by the formulations containing 45.0% RPOo with the value of 1.57 mg MDA/kg and 2.46 mg MDA/kg after 30 and 60 days of storage at 0±4 °C respectively. Based on the critical limit value of MDA concentrations at 2 mg/kg, the shelf life of reformed and cooked chicken meat formulated with palm shortening containing 22.5 or 45.0% RPOo could be extended to 30 days compared to less than 30 days at 0±4 °C for the cooked meat formulated with chicken fat or blended palm shortening without RPOo as the main source of fat. This clearly indicated that RPOo can be utilised as a natural source of antioxidant to improve oxidative stability of the reformed and cooked chicken meat during storage at 0±4 °C. Further research should be conducted to evaluate the utilisation of RPOo as an antioxidant in comparison with the commercially used antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and propyl gallate (PG) in reformed meat products.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

The authors acknowledge the scholarship and funding for this project by Malaysia Palm Oil Board (MPOB). The expertise and laboratory facilities provided by MPOB and the Faculty of Bioresources and Food Technology, Universiti Sultan Zainal Abidin (UniSZA) are also appreciated.

AUTHOR CONTRIBUTIONS

MMS and CA designed the experiments and reviewed the manuscript with NLH. NAB performed the experiments and wrote the manuscript with WAF. All authors read and approved the final version.

REFERENCES

Alina, A.R., Siti Mashitoh, A., Babji, A.S., Maznah, I., Syamsul, K.M.W. & Muhyiddin, Y. (2012). Oxidative stability of smoked chicken sausages substituted with red palm mid-fraction during chilling storage. *World Applied Sciences Journal*, 17, 62-66.

Alm, M. (2013). Animal Fats. AOCS Lipid Library, USA. Available at https://lipidlibrary.aocs.org/edible-oil-processing/animal-fats

Babji, A.S. Alina, A.R., Mohd Suria Affandi., Y., & Wan Sulaiman., W.I. (2001) Palm oil: A healthy fat substitute? *Meat International*, 11(2), 26–27

Barbut, S. (1997). Occurrence of pale soft exudative meat in mature turkey hens. *British Poultry Science*, 38, 74-77.

Buege, J. A. & Aust, S. D. (1978). Microsomal lipid peroxidation. *Methods Enzymol*, 52, 302-310.

Campo, M.M., Nute, G.R., Hughes, S.I., Enser, M., Wood, J.D. & Richardson, R.I. (2006). Flavour perception of oxidation in beef. *Meat Science*. 72(2), 303–311.

Castellini, C., Bosco, A. D., Mugnai, C. & Pedrazzoli, M. (2006). Comparison of two chicken genotypes organically reared: oxidative stability and other qualitative traits of the meat. *Italian Journal of Animal Science,* 5(1), 29-42.

Department of Statistic Malaysia (2017). Economic Census 2016 - Livestock, Department of Statistic Malaysia Official Portal. Available at https://www.dosm.gov.my/v1_/

Di Mascio, P., Kaiser, S., Sies, H. (1989). Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Archives of Biochemistry and Biophysics*. 274(2), 532-538.

Gadekar, Y. P., Sharma, B.D., Shinde, A.K., & Mendiratta, S.K. (2015). Restructured meat products-production, processing and marketing: a review. *Indian Journal of Small Ruminants*, 21(1), 1-12.

Gunstone, F.D., Harwood, J.L. & Padley, F.B.

(1986). The Lipid Handbook. London: Chapman and Hall, 76-78.

Haila, K., Lievonen, S., & Heinonen, M. (1996). Effects of lutein, lycopene, annatto, and α-tocopherol on autoxidation of triglycerides. *Journal of Agriculture and Food Chemistry*, 44, 2096-100.

Ismail, I. & Joo, S.T. (2017). Poultry meat quality in relation to muscle growth and muscle fiber characteristics. *Korean Journal for Food Science of Animal Resources*, 37(6), 873-883.

Ismail, I., Hwang, Y.H., & Joo, S.T. (2020). Meat analog as future foods: a review. Journal of Animal Science and Technology, 62(2), 111-120.

King, B. & Sibley, I. (1984). Authenticity of edible vegetable oils and fats, Part II. Palm oil and palm oil fractions. Leatherhead Food Research Association (LFRA research report no 642). Surrey, UK.

Love, J.D. (1987). Mechanism of iron catalysis of lipid oxidation in warmed- over flavorof meat. In Warmed- Over Flavor of Meat, Edited by: St. Angelo, A. J. & Bailey, M. E. 19 Orlando, FL: Academic Press

Nagendran, B., Unnithan, U.R., Choo, Y.M. & Sundram, K. (2000). Characteristics of red palm oil, a carotene and vitamin E-rich refined oil for food uses. F*ood and Nutrition Bulletin*, The United Nations University. 21(2), 189-194.

Nurkhuzaiah, K., Babji, A.S., Wan Rosli, W.I., Foo, S. P. (2015). Vitamin E contents and oxidative stability of red palm oils blended chicken nuggets during frozen storage. *The Malaysian Journal of Analytical Sciences*. 19(1), 202-212.

Oguntibeju, O. O., Esterhuyse, A. J., & Truter, E. J. (2009). Red palm oil: nutritional, physiological and therapeutic roles in improving human wellbeing and quality of life. *British Journal of Biomedical Scienc*e, 66(4), 216-222.

Resconi, V. C., Escudero, A., Beltrán, J. A., Olleta, J.L., Sañudo, C. & Campo, M. M. (2011). Color, lipid oxidation, sensory quality, and aroma compounds of beef steaks displayed under different levels of oxygen in a modified atmosphere package. *Journal of Food Science*. 77. S10-S18.

Savic, I.V. (1985). Small-scale Sausage Production, FAO Animal Production and Health Paper, 52, Food and Agriculture Organization, Rome. Available at www.fao.org/docrep/003/x6556e/X6556E01.htm

Siew, W.L., & Berger, K.G. (1986). Malaysian Palm Kernel Oil Chemical and Physical Characteristics, PORIM Technology No. 6, Palm Oil Research Institute of Malaysia, Kuala Lumpur.

Tan, S. S., Aminah, A., Zhang, G., & Babji, A. S. (2006). Optimizing palm oil and palm stearin utilization for sensory and textural properties of chicken frankfurters. *Meat Science*, 72(3), 387-397.

Wan Mohamad, W.A.F., McNaughton, D., Buckow, R., & Augustin, M.A. (2017). Stability and partitioining of beta-carotene in whey protein emulsions during storage. Food & Function, 8, 3917-3925.

Wan Rosli, W. I., Babji, A. S., Aminah, A., Foo, S. P., & Abd malik, O. (2010) Effect of retorting and oven cooking on the nutritional properties of beef frankfurters blended with palm oils. *International Journal of Food Sciences and Nutrition*, 61(5), 519-535.

Wan Rosli, W.I. (2006). Vitamin E Contents of Processed Meats Blended with Palm Oils. *Journal of Food Lipids*, 13,186–198.

Youssef, M. K., & Barbut, S. (2011). Fat reduction in comminuted meat products-effects of beef fat, regular and pre-emulsified canola oil. *Meat Science*, 87(4), 356-360.