Retention of Carotenes and Vitamin E, and Physico-chemical Changes Occurring upon Heating Red Palm Olein Using Deep-fat Fryer, Microwave Oven and Conventional Oven

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Abstract: Red palm olein is known to be high in carotenes and vitamin E (tocols) and possess various nutritional benefits. This study evaluates the effect of prolonged heating using three common cooking techniques i.e. deep-fat fryer, microwave oven and conventional oven, on the profiles of carotenes and tocopherols as well as the physico-chemical changes occurring in red palm olein when compared to conventional palm olein. Physico-chemical changes in all oils were gauged based on their peroxide, *p*-anisidine and total oxidation values, acidity, and fatty acid composition. Both red palm olein and palm olein were thermally stable based on their lower rate of hydrolytic and oxidative degradations as well as higher tocopherols retention, which allow the oils to undergo heating up to 3 hours using deep-fat fryer and conventional oven. Nevertheless, red palm olein seemed not suitable for prolonged heating processes considering lower retention of carotenes. Microwave heating also influenced the stability of phytonutrients.

Key words: red palm olein, palm olein, heating, oxidative stability, carotenes, vitamin E

1 Introduction

Palm olein essentially possess greater resistance towards thermal oxidation compared to other vegetable oils and fats¹. Due to its inherent thermal properties coupled with the presence of tocopherols (tocopherols and tocotrienols), palm olein is widely used for various cooking applications². Tocopherols, which act as antioxidant, contribute to the stability of palm olein by acting as free radical quenchers. Tocopherols can prevent hydroperoxide formation in the chain propagation step, or the decomposition process by inhibiting aldehyde formation³. Polyunsaturated oils are reported least thermal stable due to the presence of double bonds, and therefore prone to decomposition. Saturated and monounsaturated oils possess better heat stability and health profile⁴. During heat treatment, carotenoids and tocopherols synergistically protect the oils against excessive thermal degradation⁵. Carotene radicals formed during oxidation are converted back into active carotenes in the presence of tocotrienols⁵. Oxidation induces significant loss of oil quality which subsequently affects the functionality, and

nutritional values of fried products. Indeed, this reaction triggers the formation of harmful new compounds including polymers, free fatty acids and other oxidative substances⁶.

Cooking oil is commonly used for daily diet preparation. Carotenoid-rich red palm oil is beneficial as it offers vital antioxidants that enhance the well-being of the general population, and fulfil the daily requirement of fatty acids⁷. However, a dietary habit survey involving 200 pregnant Nigerian women showed high prevalence of vitamin A deficiency as a result of high episode of malaria, anaemia, and subclinical infections, i.e. upper respiratory and urinary tract infection, despite 80% of them consumed red palm oil for cooking. It is suspected that the cooking methods by these women involve excessive heating which contributed to low vitamin A viability⁸. A study has been conducted to evaluate the thermal stability of various palm products, i.e. palm oil, single- and double fractionated palm oleins, red palm olein and palm-based shortening upon 80 hours of heating at 180°C⁶. This study evaluates thermal and phyto-

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Accepted December 26, 2019 (received for review August 21, 2019)

Journal of Oleo Science ISSN 1345-8957 print / ISSN 1347-3352 online

<http://www.jstage.jst.go.jp/browse/jos/> <http://mc.manuscriptcentral.com/jjocs>

nutrient stabilities of red palm olein under common cooking techniques, i.e. deep-fat fryer, microwave oven and conventional oven, compared to the performance of palm olein. It is hypothesized that phytonutrient-rich red palm olein would possess better thermal stability compared to palm olein with all 3 cooking techniques. The outcomes of this study would provide a holistic perspective about the nutritional properties and thermal resistance of both oils for domestic cooking.

2 Materials and Methods

2.1 Materials

Red palm olein and palm olein were obtained from Carotino Sdn Bhd (Pasir Gudang, Johor) of similar batch of production. Standards for tocopherol and tocotrienol homologues (i.e. alpha, beta, gamma and delta) were purchased from Davos Life Sciences Ptd Ltd (Synapse, Singapore); 2,2,5,7,8-pentamethyl-6-hydroxy-chromane (PMC) and alpha carotene from Wako (Osaka, Japan); beta carotene and butylated hydroxytoluene from Sigma Chemical Co. (St. Louis, USA); and retinyl acetate and fatty acid methyl esters from Supelco Analytical (Bellefonte, USA). Solvents; HPLC gradient grade methanol, ethanol, 1-propanol, 2-propanol, acetonitrile, and *n*-hexane were purchased from Merck (Darmstadt, Germany). All other chemicals were purchased from R&M Chemical (Essex, UK) or System ChemAR (Shah Alam, Malaysia).

2.2 Heating techniques

All oils were subjected to heating for a total of 180 min using deep-fat fryer, microwave oven and conventional oven. About 50 g of fresh oil was collected before heating while heated oil was sampled for every 15 min across 3 hours of heating. Heated samples were allowed to cool at 60°C, flushed with nitrogen and stored at -40°C prior to subsequent analyses. The experiments for each oil and heating techniques were performed in duplicates. The protocols for each heating techniques are as follows:

2.2.1 Deep-fat fryer

The heating experiment was performed using a domestic deep-fat fryer (Cornell CDF-S3503, Klang, Malaysia). The fryer was first filled with 3.5 L of oil and gradually heated to 170 ± 10°C and remained constant at this value across 3 hours of heating. Oil was not replenished throughout the heating period.

2.2.2 Microwave oven

A domestic microwave oven (Panasonic NN-SD577M, Shanghai, China) with the capacity of 27 L was used to heat the oil. Seventy grams of oil were transferred into a ceramic cup and placed at the centre of turntable rotary plate. The sample was then exposed to microwave wattage of 550 W across the heating period at 170 ± 10°C. After

heating treatment, the microwave oven door was opened while a fan was used to circulate ambient air to facilitate cooling.

2.2.3 Conventional oven

An aliquot of 70 g was weighted into aluminum cupcake foil and kept in an oven (Astar DKL-40, Guangdong, China) at 170 ± 10°C from 0 to 180 min. Cooling procedure was also applied following similar manner as microwave oven.

2.3 Carotenes and tocols content

Carotene homologues (alpha and beta carotenes) were analysed using a Reverse-phase High Performance Liquid Chromatography (HPLC) (Agilent 1260 Infinity, Germany, UK) equipped with Agilent OpenLAB CDS Chemstation Edition Rev.C.01.05 (45) and analytical column JASCO CrestPak C18S, 4.6 × 150 mm⁹. Isocratic elution of mobile phase containing methanol and ethanol (75:25, v/v) mixture was set at a flow rate of 1 mL/min. The wavelength of 292 nm was used to identify alpha tocopherol acetate while alpha- and beta carotenes shared similar wavelength of 450 nm. The mean recovery of internal standard for alpha tocopherol acetate was 108.02 ± 5.41 %.

Tocol homologues (i.e. tocopherols and tocotrienols) were quantified using a normal-phase High Performance Liquid Chromatography (HPLC) (Agilent 1100 series, US) fitted with fluorescence spectrophotometer, Agilent ChemStation software version B.0403-SP2 (108) and analytical column Phenomenex[®] Luna 5 µ Silica (250 × 4.6 mm id, 5 µm)⁹. The mobile phase of tertiary mixture containing hexane, dioxane and isopropyl alcohol (Merck, Darmstadt, Germany) was used at the ratio of 970:25:5 (v/v) and flow rate of 1 mL min⁻¹. The fluorescence detector was set at excitation wavelength of 295 nm and emission wavelength of 325 nm. The mean recovery of internal standard (2,2,5,7,8-pentamethyl-6-hydroxy-chromane) was 109.30 ± 5.61 % for red palm olein and 102.99 ± 2.23 % for palm olein. Identification of all components were done by comparing the peak areas with relation to pure standards.

2.4 Physico-chemical analyses

The AOCS Official Methods were employed for the determination of peroxide value (PV) [Cd 8b-90]¹⁰, *p*-anisidine value (AnV) [Cd 18-90]¹¹, free fatty acid (FFA) [Ca 5a-40] and fatty acid composition [Ce 1a-13]¹². Total oxidation value (TOTOX) was calculated using the following formula: TOTOX = 2PV + AnV.

2.5 Statistical analysis

The results were expressed as mean ± standard deviation of duplicate heating experiment. Each quality parameter was evaluated in duplicate measurements. Therefore, analysis was performed as sextuple (triplicate measurements × duplicate heating experiment for physicochemical parameters) and quadruple (duplicate measurements × du-

plicate heating experiment for phytonutrients and fatty acid composition). One-way ANOVA with Tukey posthoc multiple comparison test was used to determine the difference between treatments. Pearson correlation test was used to evaluate the positive or negative interaction between parameters, type of oils and heating procedures. Statistical analysis was conducted using GraphPad Prism (version 6.00; GraphPad La Jolla, CA 9203, USA) and SPSS (version 11.5).

3 Results and Discussion

The temperature profile of red palm olein and palm olein during heating between 2 experiments was similar for deep-fat fryer, microwave oven, and conventional oven (Fig. 1).

Deep-fat frying transfers heat through convection directly from heating element, conventional oven also transfers heat through convection but uses air as heat transfer medium; while microwave oven transfers heat through frequency wave¹³. Depletion of alpha and beta carotenes in red palm olein was found to be faster than tocopherols (Table 1). Similar observation was reported by Schroeder *et al.*, and this was due to the nature of carotenes acting as the primary substrate for lipid-derived radicals or the ability of carotenes to regenerate oxidized phenols, in current case the tocopherols⁵. Alpha and beta carotenes were found to be most stable under conventional oven heating (46% and 40% remaining respectively after 180 minutes of prolonged heating). Beta carotene tends to degrade faster than alpha carotene regardless of the heating conditions tested. An antioxidant synergism between carotenes and tocopherols could clearly be seen with microwave oven heating after total depletion of alpha and beta carotenes at 135 min, whereby more than 3 times of steep reduction in total tocotrienols and total tocopherols were found (Table 1). Beta tocotrienol as well as beta, delta and gamma tocopherols were only detected in trace amounts in both red palm olein and palm olein, and hence no comparison was made on the thermal stability with the major tocopherols (alpha tocotrienol, delta tocotrienol, gamma tocotrienol and alpha tocopherol) found in both oils. Tocopherols were found to be very stable, evidenced by more than 70% retention after 180 hours of heating under all heating conditions. However, this was not the case for tocopherols in red palm olein, where close to complete depletion was observed with microwave oven heating. Tocopherols were found to be most heat-labile by microwave oven heating under magnetron radiation process. Malheiro *et al.* reported complete disappearance of alpha tocopherol in olive oil in shorter period (within 10 minutes) with microwave oven heating¹⁴. Based on percentage depletion of tocopherols in red palm oil for microwave oven heating method, alpha tocotrienol was found to be the least stable followed

by alpha tocopherol, gamma tocotrienol and lastly delta tocopherol. The pattern of reactivity was in accordance to the findings by Yoshida *et al.*¹⁵ and alpha tocopherols were found to have highest absolute antioxidant activity by side chain reaction of hydrogen donation in the presence of free radicals¹⁶.

PV measures the oxidation or rancidity of oils during storage and heating. Peroxides are intermediate oxidation products of oil which lead to the formation of a complex mixture of volatile compounds such as aldehydes, ketones, hydrocarbons, alcohols and esters¹⁷. They have also shown to occur in oils especially at elevated temperatures as well as exposure upon to oxygen and/or light. Desired level of PV in refined palm oil is less than 0.5 meq O₂ kg⁻¹ and maximum level is 1 meq O₂ kg⁻¹, and a value higher than 10 meq O₂ kg⁻¹ is considered unacceptable due to rancidity¹⁸. The fresh oil samples had desirable PV of 0.33 meq O₂ kg⁻¹ for red palm olein and 0.40 meq O₂ kg⁻¹ for palm olein (Table 2). A pattern of gradual increase in PV was observed in both test oils for all three heating techniques tested. The PV values were lowest for deep-fat fryer technique, and highest was recorded by microwave for red palm olein and conventional oven for palm olein respectively. The PVs for both samples were less than 10 meq O₂ kg⁻¹ up to 180 minutes for all three heating techniques except for microwave 11.40 meq O₂ kg⁻¹ which are considered as low oxidation. A PV however is less useful as hydroperoxides could decompose at 150°C¹⁸.

The primary oxidation products are usually measured with PV test while the secondary oxidative products were quantified from AnV test. AnV represents the level of non-volatile aldehydes, primarily, measuring presence of 2-alkenals and 2,4-alkadienals generated in the fat during the decomposition of hydroperoxides¹⁸. Desired level of AnV in refined, bleached and deodorised (RBD) palm oil is <4 unit and maximum level is 6 unit¹⁸. The fresh oil samples had desirable AnV of 1.58 for red palm oil and 1.10 palm oil respectively (Table 2). In the present study AnV increased in both samples upon heat exposure.

TOTOX value gives an overview of the oxidative state of the oil by considering primary and secondary oxidation¹⁹. TOTOX value provides a better approximation of the development of oxidative deterioration of fats and oils as it measures both hydroperoxides and secondary breakdown products. The TOTOX value of edible oils is limited to 10 unit for refined oils²⁰. The fresh oil samples had TOTOX value of 2.24 unit for red palm oil and 1.90 unit for palm oil respectively (Table 2). Similarly, during the heating process the TOTOX values increased significantly with heating time and the fastest deterioration was by microwave oven heating. Under similar oil heating conditions with conventional heating (by deep-fat fryer and hot plate), microwave oven and conventional oven; a similar trend of increase in hydroperoxides as secondary oxidation products are

Fig. 1 Temperature profiles of red palm olein and palm olein during heating. Values are expressed as mean $\pm$ SD for two different series of experiments.

Table 1 Changes in phytonutrients upon heating.

a) Tocotrienol homologues and total tocotrienols

Parameter	Time (min)	i) Red palm olein			ii) Palm olein		
		(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven	(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven
Alpha tocotrienol (mg kg ⁻¹)	0	268.10 ± 4.89 (c)	268.10 ± 4.90	258.31 ± 3.86 (a)	180.18 ± 3.87	180.18 ± 3.87	180.50 ± 2.88
	15	254.99 ± 26.47	263.06 ± 0.66	249.64 ± 4.99	166.26 ± 3.20 *(b)	176.25 ± 2.04 (a,c)	169.01 ± 1.14 *(b)
	30	251.25 ± 18.55 (b)	209.87 ± 19.70 *(a)	240.48 ± 8.97 *	163.14 ± 0.91 *(b)	157.87 ± 0.17 *(a,c)	164.21 ± 2.14 *(b)
	45	256.37 ± 18.77 (b)	153.84 ± 16.14 *(a,c)	236.08 ± 5.29 *(b)	164.46 ± 0.67 *(b)	150.70 ± 4.36 *(a,c)	166.33 ± 1.90 *(b)
	60	258.98 ± 32.90 (b)	98.70 ± 25.57 *(a,c)	226.48 ± 3.44 *(b)	162.26 ± 3.44 *(b)	155.06 ± 3.17 *(a)	156.60 ± 3.02 *
	75	250.87 ± 26.55 (b)	55.31 ± 24.36 *(a,c)	214.37 ± 5.91 *(b)	157.10 ± 2.24 *(b,c)	152.81 ± 0.88 *(a)	153.88 ± 0.33 *(a)
	90	251.98 ± 21.33 (b,c)	34.74 ± 18.21 *(a,c)	214.20 ± 5.45 *(a,b)	162.21 ± 5.61 *(b)	147.36 ± 0.36 *(a)	153.64 ± 6.12 *
	105	267.14 ± 22.25 (b,c)	38.19 ± 35.78 *(a,c)	212.50 ± 1.59 *(a,b)	163.87 ± 1.92 *(b,c)	147.76 ± 1.46 *(a)	151.23 ± 1.26 *(a,b)
	120	264.50 ± 4.65 (b,c)	26.74 ± 25.31 *(a,c)	205.99 ± 4.32 *(a,b)	167.66 ± 1.75 *(b,c)	141.04 ± 5.38 *(a)	147.04 ± 4.66 *(a)
	135	236.66 ± 20.64 (b,c)	0.00 ± 0.00 *(a,c)	201.48 ± 3.03 *(a,b)	170.27 ± 6.93 *(b,c)	142.02 ± 3.70 *(a)	145.18 ± 2.44 *(a)
	150	255.29 ± 9.81 (b,c)	3.41 ± 3.94 *(a,c)	189.47 ± 7.65 *(a,b)	165.82 ± 2.83 *(b,c)	134.08 ± 4.99 *(a)	145.79 ± 0.55 *(a,b)
Beta tocotrienol (mg kg ⁻¹)	165	234.72 ± 16.16 (b,c)	0.00 ± 0.00 *(a,c)	181.00 ± 14.36 *(a,b)	165.05 ± 5.69 *(b,c)	134.20 ± 2.91 *(a)	140.64 ± 1.22 *(a)
	180	232.48 ± 15.21 (b,c)	2.22 ± 2.58 *(a,c)	185.95 ± 5.71 *(a,b)	165.81 ± 0.75 *(b,c)	133.68 ± 0.07 *(a)	133.11 ± 5.83 *(a)
	0	22.14 ± 0.31 (c)	22.14 ± 0.31 (c)	21.52 ± 0.28 (a,b)	14.46 ± 0.48 (c)	14.46 ± 0.48 (c)	15.62 ± 0.27 (a,b)
	15	21.07 ± 1.54	21.98 ± 0.19	20.81 ± 0.28	13.62 ± 0.37 (c)	14.25 ± 0.07	14.59 ± 0.59 (a)
	30	21.47 ± 1.33	20.66 ± 0.57	20.52 ± 0.64	13.83 ± 0.51	13.53 ± 0.18 *	14.28 ± 0.66
	45	21.03 ± 1.08 (b)	18.41 ± 0.34 *(a,c)	20.74 ± 0.51 (b)	13.34 ± 0.02 *(c)	13.31 ± 0.04 *(c)	14.81 ± 0.69 (a,b)
	60	21.15 ± 1.97 (b)	15.98 ± 0.83 *(a,c)	20.45 ± 0.41 (b)	13.37 ± 0.17 *(c)	13.35 ± 0.11 *(c)	14.62 ± 0.58 (a,b)
	75	20.58 ± 1.63 (b)	12.84 ± 1.04 *(a,c)	19.55 ± 0.47 (b)	12.95 ± 0.12 *(c)	13.24 ± 0.08 *(c)	14.26 ± 0.73 (a,b)
	90	20.60 ± 1.20 (b)	10.86 ± 1.60 *(a,c)	19.80 ± 0.59 (b)	13.27 ± 0.20 *	13.37 ± 0.61 *	14.18 ± 0.57
	105	21.58 ± 1.41 (b)	10.20 ± 3.91 *(a,c)	19.81 ± 0.28 (b)	13.38 ± 0.30 *(c)	13.44 ± 0.27 *(c)	14.53 ± 0.76 (a,b)
	120	21.43 ± 0.16 (b)	9.16 ± 3.22 *(a,c)	19.74 ± 0.26 (b)	13.77 ± 0.51	13.03 ± 0.53 *(c)	14.31 ± 0.48 (b)
Delta tocotrienol (mg kg ⁻¹)	135	19.68 ± 1.23 (b)	4.66 ± 0.14 *(a,c)	19.66 ± 0.09 (b)	13.87 ± 0.75	13.00 ± 0.34 *	13.98 ± 0.57 *
	150	20.76 ± 0.55 (b,c)	4.79 ± 0.39 *(a,c)	18.96 ± 0.68 (a,b)	13.56 ± 0.35 (b)	12.45 ± 0.25 *(a,c)	14.46 ± 0.73 (b)
	165	19.51 ± 0.92 (b)	4.20 ± 0.32 *(a,c)	18.69 ± 0.88 (b)	13.52 ± 0.11 *(b,c)	12.55 ± 0.34 *(a,c)	14.27 ± 0.52 (a,b)
	180	19.44 ± 0.76 (b)	4.10 ± 0.07 *(a,c)	18.83 ± 0.36 (b)	13.36 ± 0.24 *	12.65 ± 0.55 *	13.47 ± 0.52 *
	0	115.25 ± 0.88	115.25 ± 0.88	113.49 ± 1.47	73.12 ± 0.19 (c)	73.12 ± 0.19 (c)	75.01 ± 1.05 (a,b)
	15	113.23 ± 8.20	115.07 ± 1.16	111.15 ± 2.31	68.56 ± 0.97 *(b)	73.37 ± 0.89 (a)	70.82 ± 2.22
	30	118.18 ± 8.56	111.42 ± 1.93	109.43 ± 4.00	68.06 ± 0.49 *	69.63 ± 1.41 *	69.77 ± 3.45
	45	114.31 ± 6.58 (b)	104.19 ± 1.94 (a)	111.34 ± 3.64	68.12 ± 0.03 *(c)	69.02 ± 0.65 *(c)	72.57 ± 1.10 (a,b)
	60	117.38 ± 12.69 (b)	95.67 ± 1.37 (a,c)	110.50 ± 2.54 (b)	66.16 ± 2.24 *(c)	68.79 ± 0.86 *	70.03 ± 1.13 (a)
	75	113.05 ± 9.70 (b)	81.92 ± 2.07 *(a,c)	106.62 ± 2.48 (b)	65.42 ± 0.39 *(b,c)	68.00 ± 1.61 *(a,c)	70.89 ± 1.43 (a,b)
	90	113.45 ± 6.24 (b)	74.75 ± 9.92 *(a,c)	108.70 ± 3.19 (b)	67.96 ± 0.95 *	66.35 ± 0.32 *	70.95 ± 4.02
Gamma tocotrienol (mg kg ⁻¹)	105	118.81 ± 9.56 (b)	67.92 ± 20.35 *(a,c)	107.25 ± 3.00 (b)	67.60 ± 1.24 *(c)	66.56 ± 0.91 *(c)	71.89 ± 0.65 (a,b)
	120	118.05 ± 1.61 (b)	65.15 ± 17.58 *(a,c)	106.44 ± 0.95 (b)	67.95 ± 0.52 *	65.03 ± 1.94 *(c)	70.81 ± 3.71 (b)
	135	108.06 ± 6.56 (b)	33.87 ± 1.02 *(a,c)	106.83 ± 1.52 (b)	69.35 ± 2.55 *(b)	65.43 ± 0.90 *(a,c)	70.67 ± 2.35 (b)
	150	116.83 ± 1.86 (b,c)	33.75 ± 7.70 *(a,c)	104.61 ± 3.41 *(a,b)	68.37 ± 0.96 *(b)	63.46 ± 0.81 *(a,c)	70.14 ± 0.99 (b)
	165	107.57 ± 5.38 (b)	24.51 ± 1.77 *(a,c)	104.83 ± 4.60 *(b)	67.48 ± 1.60 *(b)	62.58 ± 0.88 *(a,c)	70.31 ± 3.03 (b)
	180	107.33 ± 5.47 (b)	19.31 ± 1.70 *(a,c)	104.21 ± 1.34 *(b)	66.27 ± 0.97 *	62.94 ± 0.83 *(c)	67.69 ± 2.85 *(b)
	0	336.45 ± 6.45 (c)	336.44 ± 6.45 (c)	324.37 ± 4.60 (a,b)	219.51 ± 5.44	219.50 ± 5.45	221.49 ± 2.26
	15	309.07 ± 27.92	332.49 ± 3.49	313.56 ± 4.73	200.79 ± 3.54 *(b,c)	217.05 ± 0.16 (a,c)	206.63 ± 1.52 *(a,b)
	30	316.00 ± 25.14	301.37 ± 12.06	307.85 ± 10.66	196.32 ± 1.05 *	200.07 ± 3.09 *	203.15 ± 5.36 *
	45	303.86 ± 19.66 (b)	239.52 ± 2.89 *(a,c)	308.79 ± 8.12 (b)	196.24 ± 0.46 *(b,c)	190.00 ± 2.10 *(a,c)	209.70 ± 2.25 *(a,b)
	60	303.27 ± 35.97 (b)	169.14 ± 19.96 *(a,c)	301.57 ± 5.63 *(b)	192.24 ± 4.15 *(c)	187.39 ± 2.78 *(c)	200.99 ± 4.41 *(a,b)
Total tocotrienols (mg kg ⁻¹)	75	289.24 ± 29.04 (b)	100.36 ± 17.42 *(a,c)	284.54 ± 8.53 *(b)	185.11 ± 2.51 *(c)	182.21 ± 2.89 *(c)	200.73 ± 1.41 *(a,b)
	90	288.23 ± 22.68 (b)	62.10 ± 27.23 *(a,c)	286.71 ± 11.42 *(b)	191.54 ± 5.93 *(b)	173.74 ± 1.89 *(a,c)	200.62 ± 6.80 *(b)
	105	299.60 ± 24.57 (b)	64.30 ± 57.23 *(a,c)	286.72 ± 2.59 *(b)	192.80 ± 1.84 *(b,c)	170.75 ± 0.96 *(a,c)	201.27 ± 1.91 *(a,b)
	120	294.84 ± 2.87 (b)	47.61 ± 41.50 *(a,c)	284.32 ± 4.96 *(b)	195.42 ± 1.71 *(b)	160.35 ± 6.84 *(a,c)	196.74 ± 4.62 *(b)
	135	260.63 ± 21.36 *(b)	5.19 ± 0.34 *(a,c)	280.63 ± 3.39 *(b)	197.96 ± 8.16 *(b)	159.25 ± 2.53 *(a,c)	194.72 ± 2.11 *(b)
	150	275.42 ± 12.00 *(b)	5.54 ± 1.69 *(a,c)	264.34 ± 14.91 *(b)	192.38 ± 3.60 *(b)	148.59 ± 2.00 *(a,c)	196.65 ± 0.43 *(b)
	165	250.90 ± 16.53 *(b)	4.15 ± 0.06 *(a,c)	253.48 ± 15.14 *(b)	191.19 ± 5.93 *(b)	144.94 ± 0.70 *(a,c)	193.97 ± 4.62 *(b)
	180	244.98 ± 14.75 *(b)	2.11 ± 2.43 *(a,c)	257.98 ± 10.36 *(b)	189.37 ± 1.91 *(b,c)	142.90 ± 1.38 *(a,c)	181.18 ± 4.34 *(a,b)
	0	741.93 ± 12.47 (c)	741.93 ± 12.47 (c)	717.69 ± 8.45 (a,b)	487.25 ± 9.75	487.25 ± 9.75	492.62 ± 4.16
	15	698.37 ± 64.14	732.6 ± 5.34	695.15 ± 12.27	449.23 ± 7.96 *(b,c)	480.91 ± 2.83 (a,c)	461.05 ± 2.87 *(a,b)
	30	706.89 ± 47.19	643.32 ± 34.08	678.28 ± 24.23	441.35 ± 2.6 *	441.11 ± 4.35 *	451.42 ± 11.11 *
	45	695.58 ± 46.08 (b)	515.95 ± 17.49 *(a,c)	676.94 ± 17.48 (b)	442.16 ± 1.18 *(b,c)	423.03 ± 6.29 *(a,c)	463.42 ± 3.93 *(a,b)
	60	700.78 ± 83.49 (b)	379.49 ± 47.73 *(a,c)	659.01 ± 9.53 (b)	434.03 ± 9.62 *	424.59 ± 6.75 *(c)	442.24 ± 7.71 *(a,b)
	75	673.74 ± 66.87 (b)	250.44 ± 44.86 *(a,c)	625.07 ± 17.37 (b)	420.59 ± 4.32 *(c)	416.26 ± 4.4 *(c)	439.76 ± 3.01 *(a,b)
	90	674.26 ± 51.35 (b)	182.44 ± 56.5 *(a,c)	629.41 ± 20.62 (b)	434.98 ± 12.63 *(b)	400.82 ± 2.99 *(a,c)	439.39 ± 16.92 *(b)
	105	707.12 ± 57.76 (b)	180.62 ± 117.26 *(a,c)	626.28 ± 5.99 (b)	437.65 ± 4.94 *(b)	398.51 ± 2.79 *(a,c)	438.91 ± 2.99 *(b)
	120	698.82 ± 8.87 (b)	148.65 ± 87.61 *(a,c)	616.49 ± 10.19 (b)	444.8 ± 4.36 *(b)	379.45 ± 14.65 *(a,c)	428.9 ± 12.47 *(b)
	135	625.04 ± 49.72 (b)	43.72 ± 1.18 *(a,c)	608.61 ± 5.04 (b)	451.45 ± 18.31 *(b,c)	379.7 ± 6.97 *(a,c)	424.55 ± 6.53 *(a,b)
	150	668.3 ± 24.17 (b)	47.49 ± 13.69 *(a,c)	641.63 ± 145.05 (b)	440.12 ± 6.75 *(b,c)	358.58 ± 6.63 *(a,c)	427.04 ± 1 *(a,b)
	165	612.69 ± 38.9 *(b)	32.86 ± 2.08 *(a,c)	558 ± 34.93 *(b)	437.24 ± 11.95 *(b,c)	354.26 ± 3.97 *(a,c)	419.19 ± 8.36 *(a,b)
	180	604.23 ± 36.18 *(b)	27.73 ± 6.63 *(a,c)	566.97 ± 17.6 *(b)	434.8 ± 3.48 *(b,c)	352.18 ± 2.64 *(a,c)	395.45 ± 12.68 *(a,b)

Table 1 Continued.

b) Tocopherol homologues and total tocopherols

Parameter	Time (min)	i) Red palm olein			ii) Palm olein		
		(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven	(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven
Alpha tocopherol (mg kg ⁻¹)	0	161.64 ± 3.72	162.14 ± 3.20	157.48 ± 1.70	126.46 ± 1.32	126.82 ± 2.80	126.34 ± 1.53
	15	164.27 ± 6.42(c)	158.46 ± 1.10	151.62 ± 1.77(a)	116.75 ± 2.20 *(b)	123.15 ± 0.83(a,c)	118.40 ± 0.19 *(b)
	30	161.41 ± 13.90 (b)	129.34 ± 10.72 *(a)	148.04 ± 5.06 *	114.84 ± 0.40 *	112.51 ± 0.40 *	115.57 ± 2.85 *
	45	158.64 ± 11.29(b)	98.58 ± 10.44 *(a,c)	147.65 ± 4.76 *(b)	117.00 ± 0.16 *(b)	107.00 ± 2.30 *(a,c)	117.09 ± 1.02 *(b)
	60	161.02 ± 19.74(b)	65.53 ± 16.09 *(a,c)	142.98 ± 1.67 *(b)	116.51 ± 1.15 *(c)	113.29 ± 2.11 *	110.61 ± 2.15 *(a)
	75	155.80 ± 16.21(b)	38.34 ± 16.27 *(a,c)	133.64 ± 2.88 *(b)	112.64 ± 1.54 *(c)	111.56 ± 0.61 *(c)	108.70 ± 0.15 *(a,b)
	90	157.58 ± 12.92(b,c)	24.72 ± 11.61 *(a,c)	134.83 ± 4.03 *(a,b)	117.69 ± 4.56 *(b,c)	108.78 ± 0.24 *(a)	109.33 ± 4.25 *(a)
	105	167.10 ± 13.78(b,c)	26.43 ± 24.12 *(a,c)	132.25 ± 1.07 *(a,b)	116.61 ± 0.72 *(b,c)	110.81 ± 1.09 *(a,c)	108.41 ± 0.72 *(a,b)
	120	167.12 ± 1.90(b,c)	19.12 ± 16.98 *(a,c)	127.15 ± 2.37 *(a,b)	120.20 ± 0.93 *(b,c)	108.36 ± 3.28 *(a)	105.49 ± 2.97 *(a)
	135	150.99 ± 11.99(b,c)	0.00 ± 0.00 *(a,c)	125.62 ± 2.03 *(a,b)	122.50 ± 4.73(b,c)	109.16 ± 2.29 *(a)	105.11 ± 2.25 *(a)
	150	162.53 ± 6.73(b,c)	0.00 ± 0.00 *(a,c)	121.50 ± 3.01 *(a,b)	120.87 ± 1.68(b,c)	104.26 ± 3.50 *(a)	105.45 ± 0.39 *(a)
Beta tocopherol (mg kg ⁻¹)	165	151.09 ± 9.78(b,c)	0.00 ± 0.00 *(a,c)	123.51 ± 0.22 *(a,b)	119.43 ± 4.19 *(b,c)	104.94 ± 2.08 *(a)	102.21 ± 1.24 *(a)
	180	151.21 ± 8.41(b,c)	0.00 ± 0.00 *(a,c)	116.07 ± 3.06 *(a,b)	120.18 ± 0.72 *(b,c)	104.85 ± 0.32 *(a,c)	97.20 ± 3.75 *(a,b)
	0	5.57 ± 0.05(c)	5.57 ± 0.05(c)	5.33 ± 0.17(a,b)	4.91 ± 0.06(c)	4.91 ± 0.06(c)	4.72 ± 0.04(a,b)
	15	6.20 ± 0.22 *(b,c)	5.60 ± 0.05(a)	5.37 ± 0.18(a)	4.93 ± 0.10(c)	4.90 ± 0.10	4.75 ± 0.07(a)
	30	6.61 ± 0.08 *(b,c)	5.63 ± 0.04(a,c)	5.41 ± 0.07(a,b)	5.02 ± 0.17(c)	4.99 ± 0.06(c)	4.76 ± 0.05(a,b)
	45	6.73 ± 0.13 *(b,c)	5.70 ± 0.12(a,c)	5.38 ± 0.06(a,b)	4.83 ± 0.08(b)	4.99 ± 0.06(a,c)	4.78 ± 0.06(b)
	60	6.97 ± 0.23 *(b,c)	5.75 ± 0.12(a)	5.51 ± 0.01(a,b)	4.94 ± 0.24	5.07 ± 0.09(c)	4.76 ± 0.08(b)
	75	6.90 ± 0.15 *(b,c)	5.76 ± 0.28(a,c)	5.43 ± 0.09(a,b)	4.87 ± 0.23	5.09 ± 0.06(c)	4.80 ± 0.09(b)
	90	6.93 ± 0.10 *(b,c)	5.62 ± 0.37(a,c)	5.64 ± 0.16 *(a)	4.95 ± 0.17	5.16 ± 0.14(c)	4.73 ± 0.15(b)
	105	7.01 ± 0.10 *(b,c)	5.95 ± 0.11(a,c)	5.66 ± 0.05 *(a,b)	4.96 ± 0.18	5.09 ± 0.05(c)	4.87 ± 0.03(b)
	120	7.02 ± 0.16 *(b,c)	5.72 ± 0.44(a)	5.60 ± 0.11(a)	5.06 ± 0.13(c)	5.14 ± 0.06(c)	4.76 ± 0.11(a,b)
Delta tocopherol(mg kg ⁻¹)	135	6.82 ± 0.04 *(b,c)	5.09 ± 0.22(a,c)	5.56 ± 0.08(a,b)	5.04 ± 0.15(c)	5.17 ± 0.06 *(c)	4.84 ± 0.04(a,b)
	150	6.90 ± 0.15 *(b,c)	5.12 ± 0.33(a,c)	5.64 ± 0.20 *(a,b)	5.17 ± 0.03(c)	5.16 ± 0.06 *(c)	4.79 ± 0.06(a,b)
	165	6.75 ± 0.03 *(b)	2.58 ± 2.98 *(a,c)	5.82 ± 0.09 *(b)	5.16 ± 0.02	5.01 ± 0.15	4.89 ± 0.19
	180	6.66 ± 0.06 *(b)	2.43 ± 2.81 *(a,c)	5.75 ± 0.07 *(b)	5.11 ± 0.02(c)	5.13 ± 0.02(c)	4.75 ± 0.13(a,b)
	0	17.90 ± 0.15	17.90 ± 0.15	17.67 ± 0.32	4.05 ± 0.08	4.05 ± 0.08	4.06 ± 0.07
	15	17.84 ± 1.19	17.92 ± 0.20	17.63 ± 0.33	4.03 ± 0.04	4.01 ± 0.04	3.96 ± 0.04
	30	18.46 ± 1.25	17.61 ± 0.10	17.38 ± 0.53	3.97 ± 0.09	3.97 ± 0.06	3.96 ± 0.03
	45	18.07 ± 0.96	16.84 ± 0.16	17.67 ± 0.53	3.98 ± 0.10	4.00 ± 0.04	4.04 ± 0.04
	60	18.41 ± 1.65(b)	16.11 ± 0.42(a)	17.68 ± 0.31	3.98 ± 0.07	3.98 ± 0.08	3.96 ± 0.05
	75	17.97 ± 1.35(b)	14.23 ± 0.32 *(a,c)	16.91 ± 0.44(b)	3.95 ± 0.06	3.93 ± 0.04	4.00 ± 0.08
	90	17.94 ± 1.06(b)	13.47 ± 1.04 *(a,c)	17.18 ± 0.49(b)	3.97 ± 0.08	3.96 ± 0.04	4.05 ± 0.18
Gamma tocopherol (mg kg ⁻¹)	105	18.67 ± 1.22(b)	12.52 ± 2.38 *(a,c)	17.13 ± 0.40(b)	3.91 ± 0.02(c)	4.00 ± 0.01	4.07 ± 0.09(a)
	120	18.73 ± 0.09(b)	12.15 ± 2.19 *(a,c)	17.03 ± 0.06(b)	3.96 ± 0.03	3.93 ± 0.02	4.06 ± 0.15
	135	17.40 ± 0.84(b)	8.27 ± 0.23 *(a,c)	17.08 ± 0.23(b)	4.00 ± 0.11	3.93 ± 0.07	4.04 ± 0.13
	150	18.64 ± 0.34(b,c)	8.17 ± 0.99 *(a,c)	16.90 ± 0.47(a,b)	3.97 ± 0.07	3.94 ± 0.05	4.05 ± 0.11
	165	17.43 ± 0.92(b)	7.01 ± 0.22 *(a,c)	16.94 ± 0.86(b)	3.95 ± 0.02	3.93 ± 0.04	4.05 ± 0.16
	180	17.39 ± 0.89(b)	6.25 ± 0.30 *(a,c)	16.82 ± 0.10(b)	3.99 ± 0.06	3.97 ± 0.07	3.99 ± 0.10
	0	42.63 ± 0.56(c)	42.62 ± 0.57(c)	40.83 ± 0.42(a,b)	6.85 ± 0.23(c)	6.84 ± 0.23(c)	7.65 ± 0.10(a,b)
	15	39.33 ± 3.55	42.35 ± 0.42	39.70 ± 0.64	6.51 ± 0.15(c)	6.83 ± 0.11(c)	7.30 ± 0.23(a,b)
	30	40.17 ± 3.12	39.03 ± 1.36	39.01 ± 1.33	6.66 ± 0.32	6.59 ± 0.15	7.15 ± 0.35
	45	38.75 ± 2.42(b)	31.97 ± 0.40 *(a,c)	39.51 ± 1.32(b)	6.31 ± 0.01 *(c)	6.39 ± 0.04(c)	7.38 ± 0.45(a,b)
	60	38.87 ± 4.26(b)	23.87 ± 2.48 *(a,c)	38.85 ± 1.03(b)	6.38 ± 0.08(c)	6.44 ± 0.07(c)	7.38 ± 0.40(a,b)
Total tocopherols(mg kg ⁻¹)	75	37.35 ± 3.39(b)	15.70 ± 2.31 *(a,c)	36.63 ± 1.06 *(b)	6.25 ± 0.15 *(c)	6.34 ± 0.06 *(c)	7.16 ± 0.44(a,b)
	90	37.11 ± 2.64(b)	11.01 ± 3.50 *(a,c)	37.07 ± 1.34 *(b)	6.36 ± 0.07	6.48 ± 0.32	6.91 ± 0.40
	105	38.40 ± 2.89(b)	11.28 ± 7.20 *(a,c)	36.84 ± 0.30 *(b)	6.33 ± 0.21 *(c)	6.46 ± 0.12	7.15 ± 0.61(a)
	120	38.07 ± 0.28(b)	9.23 ± 5.30 *(a,c)	36.63 ± 0.77 *(b)	6.50 ± 0.27	6.22 ± 0.26 *	6.95 ± 0.56
	135	34.20 ± 2.54 *(b)	2.02 ± 2.33 *(a,c)	36.32 ± 0.56 *(b)	6.49 ± 0.34	6.16 ± 0.16 *	6.83 ± 0.51
	150	35.94 ± 1.23(b)	2.06 ± 2.38 *(a,c)	34.48 ± 1.55 *(b)	6.52 ± 0.22	5.96 ± 0.15 *(c)	6.95 ± 0.63(b)
	165	33.07 ± 1.92 *(b)	3.05 ± 2.08 *(a,c)	33.46 ± 1.74 *(b)	6.45 ± 0.13	5.97 ± 0.19 *(c)	6.95 ± 0.58(b)
	180	32.50 ± 1.56 *(b)	0.94 ± 1.87 *(a,c)	33.78 ± 1.36 *(b)	6.30 ± 0.15 *	6.03 ± 0.29 *	6.58 ± 0.50
	0	227.74±3.24(c)	228.24±3.88(c)	221.31±2.2(b,a)	142.27±1.48	142.62±2.94	142.77±1.6
	15	227.63±11.3	224.32±1.76	214.33±2.37	132.22±2.37 *(b)	138.9±0.76(a,c)	134.41±0.19 *(b)
	30	226.65±18.34(b)	191.62±12.19(a)	209.84±6.51 *	130.5±0.36 *	128.06±0.6 *(c)	131.45±2.74 *(b)
Total tocopherols	45	222.2±14.79(b)	153.09±10.74 *(a,c)	210.21±6.2 *(b)	132.13±0.35 *(b)	122.39±2.33 *(a,c)	133.29±1.47 *(a)
	60	225.28±25.87(b)	111.26±19.01 *(a,c)	205.02±2.54 *(b)	131.82±1.03 *(c)	128.77±2.17 *	126.69±2.58 *(a)
	75	218.02±21.1(b)	74.03±19.16 *(a,c)	192.6±3.77 *(b)	127.71±1.4 *(c)	126.93±0.64 *(c)	124.66±0.45 *(b,a)
	90	219.56±16.66(b,c)	54.82±16.06 *(a,c)	194.73±5.39 *(a,b)	132.96±4.51 *(b,c)	124.38±0.62 *(a)	125.02±4.02 *(a)
	105	231.19±17.99(b)	56.18±33.81 *(a,c)	191.88±1.58 *(b)	131.81±1.03 *(b,c)	126.36±1.05 *(a,c)	124.49±0.74 *(a,b)
	120	230.93±2.22(b,c)	46.23±24.85 *(a,c)	186.41±2.97 *(a,b)	135.72±1.24 *(b,c)	123.65±3.49 *(a)	121.27±2.46 *(a)
	135	209.42±15.4(b,c)	15.38±2.46 *(a,c)	184.57±2.5 *(a,b)	138.03±5.29(b,c)	124.42±2.39 *(a)	120.82±2.04 *(a)
	150	224.02±8.14(b,c)	15.34±3.52 *(a,c)	178.51±4.16 *(a,b)	136.53±1.38(b,c)	119.32±3.56 *(a)	121.24±0.48 *(a)
	165	208.34±12.59(b,c)	12.64±4.25 *(a,c)	179.72±2.77 *(a,b)	134.99±4.07 *(b,c)	119.86±2.13 *(a)	118.11±0.92 *(a)
	180	207.75±10.81(b,c)	9.61±4.51 *(a,c)	172.42±4.08 *(a,b)	135.59±0.75 *(b,c)	119.97±0.46 *(a,c)	112.52±3.29 *(a,b)

Table 1 Continued.

c) Total tocots, alpha- and beta-carotenes

Parameter	Time (min)	i) Red palm olein			ii) Palm olein		
		(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven	(a) Deep-fat fryer	(b) Microwave oven	(c) Conventional oven
Total tocots (mg kg ⁻¹)	0	969.67±10.21(c)	970.17±16.34(c)	939±10.56(b,a)	629.52±10.55	629.87±12.66	635.38±5.72
	15	926±75.39	956.92±7.09	909.48±14.01	581.45±10.25 *(b,c)	619.81±3.27(a,c)	595.46±2.85 *(a,b)
	30	933.54±64.9(b)	834.94±46.26(a)	888.12±30.04	571.85±2.95 *	569.17±4.93 *	582.87±13.85 *
	45	917.78±60.86(b)	669.05±28.14 *(a,c)	887.15±22.93(b)	574.29±1.53 *(b,c)	545.42±7.71 *(a,c)	596.71±5.35 *(a,b)
	60	926.06±109.35(b)	490.75±66.73 *(a,c)	864.03±11.43(b)	565.84±9.71 *	553.37±8.68 *	568.93±10.18 *
	75	891.76±87.97(b)	324.47±64.02 *(a,c)	817.68±20.39 *(b)	548.29±4.52 *(c)	543.19±4.34 *(c)	564.42±2.86 *(a,b)
	90	893.82±68.02(b)	237.26±72.53 *(a,c)	824.14±25.25 *(b)	567.94±16.49 *	525.2±3.56 *	564.41±20.91 *
	105	938.31±75.75(b)	236.8±151.07 *(a,c)	818.16±7.5 *(b)	569.46±5.74 *(b)	524.87±3.09 *(a,c)	563.4±2.94 *(b)
	120	929.75±11.08(b,c)	194.88±112.45 *(a,c)	802.89±12.55 *(a,b)	580.52±5.56 *(b,c)	503.1±16.97 *(a,c)	550.16±14.93 *(a,b)
	135	834.46±65.1(b,c)	59.09±3.62 *(a,c)	793.18±7.37 *(a,b)	589.48±23.59 *(b,c)	504.12±8.7 *(a,c)	545.37±8.55 *(a,b)
	150	892.31±32.3(b,c)	62.83±17.19 *(a,c)	820.15±147.66 *(a,b)	576.66±7.47 *(b,c)	477.9±9.29 *(a,c)	548.28±1.33 *(a,b)
	165	821.03±51.49(b,c)	45.5±4.15 *(a,c)	737.73±37.69 *(a,b)	572.23±16 *(b,c)	474.12±5.17 *(a,c)	537.3±9.26 *(a,b)
	180	811.99±46.99(b,c)	37.34±11.01 *(a,c)	739.39±20.88 *(a,b)	570.39±4.14 *(b,c)	472.15±3.05 *(a,c)	507.97±15.96 *(a,b)
Alpha carotene (mg kg ⁻¹)	0	157.74 ± 10.23(b,c)	152.98 ± 16.38(a)	170.47 ± 8.87(a)	n.d.	n.d.	n.d.
	15	121.88 ± 5.29 *(b,c)	150.39 ± 11.97(a,c)	160.96 ± 2.79(a,b)	n.d.	n.d.	n.d.
	30	109.77 ± 6.09 *(b,c)	138.25 ± 2.07(a,c)	153.48 ± 3.99(a,b)	n.d.	n.d.	n.d.
	45	106.55 ± 10.21 *(b,c)	92.54 ± 4.08 *(a,c)	146.80 ± 2.35 *(a,b)	n.d.	n.d.	n.d.
	60	92.10 ± 0.78 *(b,c)	61.92 ± 9.64 *(a,c)	139.39 ± 0.53 *(a,b)	n.d.	n.d.	n.d.
	75	81.96 ± 3.53 *(b,c)	29.83 ± 0.71 *(a,c)	130.96 ± 2.70 *(a,b)	n.d.	n.d.	n.d.
	90	71.22 ± 3.24 *(b,c)	15.98 ± 9.85 *(a,c)	123.17 ± 3.24 *(a,b)	n.d.	n.d.	n.d.
	105	60.99 ± 1.52 *(b,c)	17.41 ± 18.70 *(a,c)	118.64 ± 11.39 *(a,b)	n.d.	n.d.	n.d.
	120	57.47 ± 15.76 *(b,c)	11.35 ± 11.92 *(a,c)	107.68 ± 17.15 *(a,b)	n.d.	n.d.	n.d.
	135	47.30 ± 1.20 *(b,c)	0.00 ± 0.00 *(a,c)	95.71 ± 10.91 *(a,b)	n.d.	n.d.	n.d.
	150	40.21 ± 1.68 *(b,c)	0.00 ± 0.00 *(a,c)	103.20 ± 3.17 *(a,b)	n.d.	n.d.	n.d.
	165	32.61 ± 4.46 *(b,c)	0.00 ± 0.00 *(a,c)	79.28 ± 5.22 *(a,b)	n.d.	n.d.	n.d.
	180	30.38 ± 2.59 *(b,c)	0.00 ± 0.00 *(a,c)	78.15 ± 11.48 *(a,b)	n.d.	n.d.	n.d.
Beta carotene (mg kg ⁻¹)	0	155.75 ± 8.79	160.06 ± 17.93	173.70 ± 5.68	n.d.	n.d.	n.d.
	15	108.98 ± 4.57 *(b,c)	152.30 ± 10.29(a)	166.43 ± 6.21(a)	n.d.	n.d.	n.d.
	30	91.83 ± 2.35 *(b,c)	134.28 ± 10.33 *(a,c)	153.73 ± 5.14(a,b)	n.d.	n.d.	n.d.
	45	77.40 ± 3.22 *(c)	82.18 ± 5.00 *(c)	144.96 ± 1.76 *(a,b)	n.d.	n.d.	n.d.
	60	68.12 ± 0.31 *(b,c)	49.48 ± 10.75 *(a,c)	135.56 ± 1.31 *(a,b)	n.d.	n.d.	n.d.
	75	59.56 ± 1.87 *(b,c)	20.70 ± 0.09 *(a,c)	125.16 ± 4.47 *(a,b)	n.d.	n.d.	n.d.
	90	50.24 ± 1.76 *(b,c)	10.57 ± 6.85 *(a,c)	125.39 ± 7.46 *(a,b)	n.d.	n.d.	n.d.
	105	42.23 ± 1.76 *(b,c)	12.25 ± 12.85 *(a,c)	109.44 ± 10.66 *(a,b)	n.d.	n.d.	n.d.
	120	43.64 ± 4.62 *(b,c)	7.09 ± 8.19 *(a,c)	123.47 ± 11.17 *(a,b)	n.d.	n.d.	n.d.
	135	31.39 ± 0.93 *(b,c)	0.00 ± 0.00 *(a,c)	105.40 ± 15.97 *(a,b)	n.d.	n.d.	n.d.
	150	26.37 ± 1.46 *(b,c)	0.00 ± 0.00 *(a,c)	85.59 ± 7.48 *(a,b)	n.d.	n.d.	n.d.
	165	20.60 ± 3.46 *(b,c)	0.00 ± 0.00 *(a,c)	67.69 ± 4.87 *(a,b)	n.d.	n.d.	n.d.
	180	18.97 ± 2.02 *(b,c)	0.00 ± 0.00 *(a,c)	68.80 ± 8.52 *(a,b)	n.d.	n.d.	n.d.

Values are expressed as mean ± SD (replicate analysis x 2 experiments). Data were measured by One-way Anova with Tukey posthoc multiple comparison tests to assess the differences between groups; *($p < 0.05$) compared to 0 minutes within group. Mean values followed by different letters (a,b,c) are significant different ($p < 0.05$) between groups for different heating technique at same time point. n.d. (not detectable).

formed had been reported^{14, 21–27}. In contrary to the current study, Mahmoud *et al.* and Caponio *et al.* reported that microwave and conventional oven heating had no difference in terms of oxidation products^{28, 29}. However, it is a point to note that duration of heating for both studies was rather short (30 minutes) to exhibit an effect. In accordance to the current observation, Poiana reported a higher oxidation degree by microwave oven as compared to conventional heating upon longer heating period (240 minutes)²⁶.

FFA is one of the most important indicators of oil deteri-

oration during heating. The formation of FFA is due to the hydrolysis of triacylglycerol and hydroperoxide decomposition in oil during heating in the presence of moisture and air³⁰. According to Malaysian Standard for Palm Oil Specifications, FFA (as palmitic) content of refined oils should be less than 0.1%³¹. The levels in initial fresh test oil were 0.06 ± 0.01% in palm olein and 0.07 ± 0.01% in red palm olein (Table 2). The United States Department of Agriculture (USDA) requires the frying oils to be discarded when the free fatty acid (FFA) content in the oil exceeds 2%¹⁸. A

Table 2 Changes in PV, AnV, TOTOX and FFA upon heating.

Parameter	Time	i) Red palm olein			ii) Palm Olein		
		(a) Deep Fryer	(b)Microwave	(c) Oven	(a) Deep Fryer	(b)Microwave	(c) Oven
PV (meq O ₂ kg ⁻¹)	0	0.33 ± 0.05	0.33 ± 0.08	0.33 ± 0.05	0.43 ± 0.05	0.38 ± 0.08	0.40 ± 0.06
	15	1.20 ± 0.09(b)	1.73 ± 0.18 *(a,c)	1.00 ± 0.14 *(b)	0.38 ± 0.08(b,c)	1.46 ± 0.17 *(a,c)	0.90 ± 0.09 *(a,b)
	30	1.50 ± 0.14(b)	2.05 ± 0.10 *(a,c)	1.53 ± 0.08 *(b)	0.45 ± 0.05(b,c)	1.55 ± 0.22 *(a)	1.47 ± 0.08 *(a)
	45	1.65 ± 0.10(b)	2.81 ± 0.22 *(a,c)	2.03 ± 0.10 *(a,b)	0.48 ± 0.08(b,c)	1.68 ± 0.17 *(a,c)	1.86 ± 0.08 *(a,b)
	60	1.76 ± 0.08(b,c)	3.99 ± 0.14 *(a,c)	2.26 ± 0.12 *(a,b)	0.57 ± 0.14(b,c)	1.86 ± 0.15 *(a)	1.93 ± 0.10 *(a)
	75	1.06 ± 0.08(b,c)	5.46 ± 0.17 *(a,c)	2.75 ± 0.10 *(a,b)	0.60 ± 0.13(b,c)	2.06 ± 0.20 *(a)	1.95 ± 0.08 *(a)
	90	2.06 ± 0.08 *(b,c)	5.89 ± 0.20 *(a,c)	2.83 ± 0.16 *(a,b)	0.63 ± 0.05 *(b,c)	2.33 ± 0.23 *(a)	2.10 ± 0.13 *(a)
	105	2.11 ± 0.04 *(b,c)	6.44 ± 0.17 *(a,c)	3.75 ± 0.15 *(a,b)	0.69 ± 0.14 *(b,c)	2.88 ± 0.15 *(a,c)	4.30 ± 0.21 *(a,b)
	120	2.21 ± 0.04 *(b,c)	6.64 ± 0.18 *(a,c)	4.01 ± 0.22 *(a,b)	0.70 ± 0.11 *(b,c)	4.38 ± 0.36 *(a,c)	5.78 ± 0.10 *(a,b)
	135	2.26 ± 0.05 *(b,c)	7.45 ± 0.42 *(a,c)	4.06 ± 0.12 *(a,b)	0.72 ± 0.08 *(b,c)	5.46 ± 0.24 *(a,c)	6.18 ± 0.13 *(a,b)
	150	2.36 ± 0.10 *(b,c)	8.45 ± 0.28 *(a,c)	4.25 ± 0.17 *(a,b)	0.85 ± 0.11 *(b,c)	5.96 ± 0.32 *(a,c)	6.36 ± 0.10 *(a,b)
	165	2.55 ± 0.18 *(b,c)	9.34 ± 0.13 *(a,c)	4.86 ± 0.16 *(a,b)	1.47 ± 0.12 *(b,c)	6.47 ± 0.38 *(a)	6.71 ± 0.22 *(a)
	180	3.13 ± 0.08 *(b,c)	11.40 ± 0.68 *(a,c)	5.54 ± 0.08 *(a,b)	2.60 ± 0.36 *(b,c)	6.87 ± 0.29 *(a)	6.84 ± 0.15 *(a)
AnV (unit)	0	1.55 ± 0.08	1.62 ± 0.05	1.58 ± 0.08	1.04 ± 0.05	0.94 ± 0.08	1.10 ± 0.20
	15	10.62 ± 0.50(b,c)	3.68 ± 0.34 *(a,c)	2.18 ± 0.13(a,b)	9.09 ± 1.10 *(b,c)	1.99 ± 0.27(a,c)	1.46 ± 0.17(a,b)
	30	11.50 ± 1.92 *(b,c)	6.72 ± 0.53 *(a,c)	2.31 ± 0.24(a,b)	9.41 ± 1.02 *(b,c)	3.96 ± 0.07 *(a,c)	2.21 ± 0.13 *(a,b)
	45	13.22 ± 1.23 *(b,c)	7.05 ± 1.00 *(a,c)	2.49 ± 0.26(a,b)	10.07 ± 0.94 *(b,c)	12.37 ± 1.98 *(a,c)	2.33 ± 0.32 *(a,b)
	60	15.12 ± 1.66 *(b,c)	11.58 ± 0.64 *(a,c)	2.55 ± 0.20 *(a,b)	10.21 ± 1.06 *(b,c)	14.47 ± 1.07 *(a,c)	3.90 ± 0.19 *(a,b)
	75	16.56 ± 0.44 *(b,c)	13.05 ± 0.97 *(a,c)	2.69 ± 0.39 *(a,b)	11.09 ± 1.00 *(b,c)	15.34 ± 0.75 *(a,c)	4.00 ± 0.11 *(a,b)
	90	18.38 ± 1.15 *(b,c)	16.13 ± 0.52 *(a,c)	2.89 ± 0.18 *(a,b)	12.00 ± 1.44 *(b,c)	16.36 ± 0.99 *(a,c)	4.00 ± 0.09 *(a,b)
	105	19.58 ± 1.30 *(b,c)	17.66 ± 1.22 *(a,c)	3.48 ± 0.42 *(a,b)	12.11 ± 1.50 *(b,c)	18.66 ± 1.70 *(a,c)	5.35 ± 0.31 *(a,b)
	120	20.53 ± 1.54 *(c)	19.52 ± 0.97 *(c)	5.63 ± 0.26 *(a,b)	12.38 ± 1.17 *(b,c)	20.05 ± 0.68 *(a,c)	6.47 ± 0.67 *(a,b)
	135	22.18 ± 1.90 *(c)	21.50 ± 1.59 *(c)	7.11 ± 0.36 *(a,b)	13.06 ± 1.03 *(b,c)	20.16 ± 0.81 *(a,c)	6.70 ± 0.15 *(a,b)
	150	22.90 ± 1.86 *(c)	22.63 ± 0.96 *(c)	7.43 ± 0.44 *(a,b)	13.31 ± 1.57 *(b,c)	21.25 ± 0.79 *(a,c)	6.98 ± 0.61 *(a,b)
	165	24.28 ± 2.26 *(c)	25.24 ± 1.25 *(c)	9.19 ± 0.55 *(a,b)	13.47 ± 1.25 *(b,c)	22.59 ± 1.03 *(a,c)	7.15 ± 0.17 *(a,b)
	180	24.53 ± 1.12 *(c)	25.88 ± 0.83 *(c)	14.24 ± 1.31 *(a,b)	13.75 ± 1.41 *(b,c)	23.73 ± 0.33 *(a,c)	8.41 ± 0.31 *(a,b)
TOTOX (unit)	0	2.22 ± 0.06	2.28 ± 0.18	2.24 ± 0.13	1.91 ± 0.13	1.71 ± 0.18	1.90 ± 0.26
	15	13.01 ± 0.57 *(b,c)	7.14 ± 0.67 *(a,c)	4.18 ± 0.24 *(a,b)	9.85 ± 1.10 *(b,c)	4.92 ± 0.42 *(a,c)	3.26 ± 0.19 *(a,b)
	30	14.49 ± 1.76 *(b,c)	10.81 ± 0.61 *(a,c)	5.37 ± 0.16 *(a,b)	10.31 ± 1.03 *(b,c)	7.05 ± 0.50 *(a,c)	5.15 ± 0.27 *(a,b)
	45	16.51 ± 1.37 *(b,c)	12.67 ± 1.34 *(a,c)	6.55 ± 0.27 *(a,b)	11.04 ± 1.02 *(b,c)	15.73 ± 1.82 *(a,c)	6.06 ± 0.42 *(a,b)
	60	18.65 ± 1.78 *(b,c)	19.56 ± 0.70 *(a,c)	7.08 ± 0.35 *(a,b)	11.34 ± 1.17 *(b,c)	18.20 ± 1.17 *(a,c)	7.77 ± 0.28 *(a,b)
	75	20.49 ± 0.49 *(b,c)	23.97 ± 1.24 *(a,c)	8.19 ± 0.46 *(a,b)	12.28 ± 1.12 *(b,c)	19.47 ± 0.97 *(a,c)	7.89 ± 0.27 *(a,b)
	90	22.51 ± 1.26 *(b,c)	27.92 ± 0.87 *(a,c)	8.55 ± 0.35 *(a,b)	13.26 ± 1.45 *(b,c)	21.02 ± 1.25 *(a,c)	8.20 ± 0.21 *(a,b)
	105	23.81 ± 1.33 *(b,c)	30.54 ± 1.47 *(a,c)	10.98 ± 0.55 *(a,b)	13.49 ± 1.60 *(b,c)	24.42 ± 1.72 *(a,c)	13.94 ± 0.30 *(a,b)
	120	24.96 ± 1.49 *(b,c)	32.79 ± 1.12 *(a,c)	13.65 ± 0.47 *(a,b)	13.78 ± 1.24 *(b,c)	28.81 ± 0.53 *(a,c)	18.03 ± 0.71 *(a,b)
	135	26.71 ± 1.92 *(b,c)	36.40 ± 1.03 *(a,c)	15.23 ± 0.40 *(a,b)	14.49 ± 1.14 *(b,c)	31.08 ± 1.06 *(a,c)	19.06 ± 0.37 *(a,b)
	150	27.63 ± 1.86 *(b,c)	39.54 ± 0.98 *(a,c)	15.92 ± 0.65 *(a,b)	15.00 ± 1.55 *(b,c)	33.16 ± 1.35 *(a,c)	19.70 ± 0.76 *(a,b)
	165	29.38 ± 2.21 *(b,c)	43.92 ± 1.40 *(a,c)	18.91 ± 0.75 *(a,b)	16.40 ± 1.33 *(b,c)	35.54 ± 1.68 *(a,c)	20.57 ± 0.57 *(a,b)
	180	30.79 ± 1.08 *(b,c)	48.68 ± 1.71 *(a,c)	25.32 ± 1.41 *(a,b)	18.95 ± 2.08 *(b,c)	37.48 ± 0.72 *(a,c)	22.09 ± 0.46 *(a,b)
FFA (%)	0	0.07 ± 0.00	0.07 ± 0.00	0.07 ± 0.01	0.06 ± 0.00(b)	0.05 ± 0.00(a,c)	0.06 ± 0.00(b)
	15	0.07 ± 0.00	0.07 ± 0.00	0.07 ± 0.00	0.05 ± 0.00(c)	0.05 ± 0.00(c)	0.06 ± 0.00(b,a)
	30	0.07 ± 0.00	0.07 ± 0.00	0.07 ± 0.00	0.07 ± 0.01 *(b)	0.05 ± 0.00(a,c)	0.06 ± 0.00 *(b)
	45	0.07 ± 0.01	0.07 ± 0.00	0.07 ± 0.00	0.08 ± 0.00 *(b,c)	0.05 ± 0.00(a,c)	0.06 ± 0.00 *(a,b)
	60	0.07 ± 0.00	0.07 ± 0.00	0.07 ± 0.00	0.09 ± 0.00 *(b,c)	0.05 ± 0.00(a,c)	0.06 ± 0.00 *(a,b)
	75	0.07 ± 0.00(c)	0.07 ± 0.00(c)	0.08 ± 0.00 *(a,b)	0.09 ± 0.00 *(b,c)	0.06 ± 0.00 *(a,c)	0.07 ± 0.00 *(a,b)
	90	0.07 ± 0.00(c)	0.07 ± 0.00	0.08 ± 0.01 *(a)	0.09 ± 0.00 *(b,c)	0.06 ± 0.00 *(a,c)	0.07 ± 0.00 *(a,b)
	105	0.07 ± 0.00(c)	0.07 ± 0.009(c)	0.08 ± 0.00 *(a,b)	0.10 ± 0.00 *(b,c)	0.06 ± 0.00 *(a,c)	0.07 ± 0.00 *(a,b)
	120	0.07 ± 0.00(c)	0.07 ± 0.00(c)	0.09 ± 0.00 *(a,b)	0.10 ± 0.00 *(b,c)	0.06 ± 0.01 *(a,c)	0.07 ± 0.00 *(a,b)
	135	0.07 ± 0.00(c)	0.07 ± 0.00(c)	0.09 ± 0.00 *(a,b)	0.10 ± 0.00 *(b,c)	0.07 ± 0.01 *(a,c)	0.08 ± 0.00 *(a,b)
	150	0.07 ± 0.00(c)	0.08 ± 0.00 *(c)	0.09 ± 0.00 *(a,b)	0.10 ± 0.00 *(b,c)	0.07 ± 0.01 *(a,c)	0.08 ± 0.00 *(a,b)
	165	0.07 ± 0.00(b,c)	0.09 ± 0.00 *(a)	0.09 ± 0.00 *(a)	0.10 ± 0.00 *(b,c)	0.07 ± 0.01 *(a,c)	0.08 ± 0.00 *(a,b)
	180	0.07 ± 0.00(b,c)	0.09 ± 0.00 *(a,c)	0.09 ± 0.00 *(a,b)	0.11 ± 0.00 *(b,c)	0.08 ± 0.01 *(a,c)	0.09 ± 0.00 *(a,b)

Values are expressed as mean ± SD (Triplicate analysis x 2 experiments). Data were measured by One-way Anova with Tukey posthoc multiple comparison tests to assess the differences between groups; * ($p < 0.05$) compared to 0 minutes within group. Mean values followed by different letters (a,b,c) are significant different ($p < 0.05$) between groups for different heating technique at same time point.

desirable FFA level in fresh frying oil is 0.03% to 0.05%. The FFA content in absorbed frying oils used for snack food products ranges from 0.25% to 0.40%. A portion of frying oil will be replaced with fresh oil once the FFA level exceeds 0.35%¹⁸⁾. It is a standard procedure for established snack food industry to discard the frying oil once the FFA level reaches end point. The end point of FFA varies depending on type of fried food eg. 2 to 2.5% for breaded and coated food, 0.5% for instant noodles and potato chips whereas 1% is applied for pre-fried French fries³²⁾. In our study, the FFA contents significantly increased time dependently with heating at 180°C, however the increase was very small and was within regulatory guidelines. No significant difference ($p < 0.05$) in FFA levels were found throughout the heating period with red palm olein for deep-fat fryer (Table 2). Hence in the current study, no major hydrolytic degradation was observed with regards to FFA content in both test fats studied. Similar to current study, heating oil itself at 180°C did not cause major triacylglycerol hydrolysis^{14, 22, 23, 27, 33, 34)}. However, in the presence of food matrix, the acidity values rapidly increased probably due to lipases reaction^{6, 35-40)}.

No trans oleic and linoleic acid were found in the fresh and heated oils. The degree of oxidative deterioration parameter, the ratio of C18:2/C16:0 also remained stable throughout the heating period for all three tested cooking techniques (Table 3). Palm olein blended with canola oil was found to show better oxidative stability based on C18:2/C16:0 than pure canola oil upon microwave oven heating²⁷⁾. Most papers on cooking oils have reported a reduction in unsaturated fatty acids (MUFA and PUFA)^{24, 27, 35)} and increase in trans-fat content^{18, 35)} upon prolonged heating.

Under similar oil heating conditions with conventional heating (by deep-fat fryer and hot plate), microwave oven and conventional oven; a similar trend of increase in hydroperoxides as secondary oxidation products are formed had been reported by other groups in several oils: palm olein⁴¹⁾, sunflower oil^{25, 41)}, palm olein and sunflower oil blend^{24, 25, 41, 42)}, extra virgin olive oil^{14, 21)}, virgin olive oil^{14, 22, 23)}, pork lard, rapeseed oil, groundnut oil²⁵⁾, canola oil²⁴⁾, grape seed oil⁴²⁾. Contrasting with our current study, Mahmoud *et al.* and Caponio *et al.* reported that there was no difference between microwave and conventional oven heating in terms of oxidation products in virgin olive oil^{28, 29)}, sunflower oil²⁹⁾ and peanut oil²⁹⁾. However, it is important to note that duration of heating for both of the afore mentioned studies was rather too short (30 minutes) to exhibit an effect. We managed to observe significant changes for PV, AnV and TOTOX at 15 min with all the heating techniques, but changes in microwave oven and conventional oven heating were only evident after 45 min for tocotrienols and 75 min for FFA for antioxidant rich red palm olein. In accordance with our current observations, Poiana also re-

ported a higher degree of oxidation with the microwave oven as compared to conventional heating upon longer heating periods (240 min)²⁶⁾.

Positive correlation was observed within the groups of phytonutrients (Tables 4 and 5(a)) and physico-chemical (Tables 4 and 5(b)) parameters interactions respectively. Protective role of phytonutrients on physico-chemical parameters were shown with strong negative correlation on both oils tested (Table 4(c)). Phytonutrient-rich red palm olein exhibited stronger correlation on interaction "between phytonutrients" (Table 4(a)) and "between phytonutrients and physico-chemical parameters" (Table 4(c)) respectively as compared to palm olein (Tables 5(a) and (c)). Microwave oven had the strongest association between the parameters, followed by conventional oven and lastly deep-fat fryer (medium correlation). This implies that phytonutrients could be retained better and physico-chemical parameters was least affected with deep-fat fryer technique, followed by conventional oven and lastly microwave oven.

The fact that PV, AnV, TOTOX and FFA values measured in red palm oil appeared higher than that in palm oil was mainly due to the presence and interference of carotenoid pigments in the colorimetric method employed⁴³⁾. In addition, we did not include food matrix and replenish the oil during heating procedure as we intended to check retention of tocopherols and carotenoids upon heating.

4 Conclusion

Based on the present study, it can be concluded that red palm olein and palm olein possess good thermal stability based on their low rate of hydrolytic and oxidative degradation. Phytonutrients particularly tocopherols are better retained when heat transfer is done by convection cooking i.e. deep-fat fryer and conventional oven heating for both oils. However, red palm olein may not be suitable for longer heating processes when carotene retention is of concern. Microwave heating influenced the stability of phytonutrients in red palm olein adversely.

Acknowledgments

The authors thank the Director-General of the Malaysian Palm Oil Board for permission to publish this study. Sincere acknowledgements for technical support from Ghazali Abd Razak, Dr Fu Ju Yen and Puvaneswari Meganathan. We thank research assistants Fatmawati Othman and Noraqmar Shafie; and practical trainees, Nor Hafizah Md Said, Azrul Arif Mohd Said, Samantha Ling Yuan Ci and Shalini Selvarajah.

Table 3 Percentage of fatty acid composition of test oils upon heating.

i) Red palm olein

a) Deep fryer

Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	41.63±0.71(c)	41.53±0.62(b)	41.6±0.63(b)	41.5±0.70	41.74±0.62(b)	42.87±2.55	43.88±5.07	41.77±0.7	41.73±0.76	41.88±0.76	41.9±0.98	42.19±0.76	41.94±0.89
C12:0	0.23±0.04	0.23±0.05	0.32±0.14	0.26±0.01	0.22±0.08	0.46±0.36	1.49±2.09	0.26±0.01	0.27±0.01	0.44±0.34	0.59±0.38	0.58±0.37	0.49±0.29
C14:0	0.99±0.04	0.97±0.03	0.97±0.02	0.98±0.03	1.01±0.02	2.11±2.27	2.35±2.75	0.98±0.04	0.99±0.04	1±0.02	1±0.03	1.01±0.02	1±0.04
C16:0	36.26±0.57	36.2±0.57	36.04±0.36	36.04±0.54	36.36±0.52	35.62±1.1	35.65±0.56	36.31±0.49	36.32±0.6	36.3±0.45(b)	36.2±0.53(b)	36.44±0.39(b)	36.25±0.51(b)
C18:0	3.66±0.09	3.69±0.09	3.67±0.09	3.70±0.07	3.67±0.09	3.64±0.17	3.56±0.2	3.7±0.09	3.69±0.09	3.72±0.05	3.7±0.06	3.72±0.06	3.73±0.06
C20:0	0.34±0.02	0.35±0.02	0.35±0.02	0.35±0.02	0.34±0.03	0.34±0.02	0.33±0.02	0.35±0.02	0.34±0.02	0.35±0.01	0.34±0.02	0.35±0.02	0.35±0.02
MUFA	45.7±0.38	45.94±0.37	45.72±0.37	46.02±0.37	45.82±0.53	44.84±1.84	44.02±4.06	45.77±0.4	45.83±0.45	45.86±0.64	45.75±0.69	45.7±0.61	45.7±0.56
C16:1	0.24±0.04	0.21±0.05	0.24±0.04	0.17±0.03	0.21±0.05	0.24±0.05	0.25±0.14	0.23±0.04	0.23±0.05	0.17±0.03	0.21±0.06	0.17±0.03	0.28±0.22
C18:1	45.3±0.34	45.57±0.39	45.32±0.35	45.68±0.63	45.46±0.56	44.54±1.83	43.72±3.86	45.39±0.37	45.44±0.41	45.54±0.68	45.38±0.7	45.37±0.65	45.26±0.53
C20:1	0.16±0.01	0.17±0.01	0.17±0.01	0.16±0.01	0.16±0.01	0.15±0.01	0.16±0.01	0.16±0.01	0.16±0.01	0.16±0.01	0.17±0.01	0.16±0.01	0.16±0.01
PUFA	12.42±0.10	12.42±0.31	12.46±0.13	12.48±0.11(b)	12.31±0.10(b)	12.02±0.49	11.96±0.89	12.2±0.15(b)	12.18±0.15(b)	12.23±0.15(b)	12.19±0.15(b)	12.11±0.19(b)	12.31±0.3(b)
C18:2 n6	12.06±0.11	12.06±0.32	12.10±0.13	12.13±0.12(b)	11.96±0.10	11.68±0.48	11.61±0.9	11.85±0.15(b)	11.84±0.15(b)	11.88±0.16(b)	11.85±0.16(b)	11.77±0.2(b)	11.97±0.31(b)
C18:3 n6	0.36±0.01	0.36±0.01	0.36±0.01	0.35±0.01	0.35±0.01	0.34±0.01(c)	0.35±0.02	0.35±0.01	0.35±0.02	0.35±0.01(b)	0.34±0.01(b)	0.35±0.01(b)	0.34±0.01(b)
C16:0	0.33±0.01	0.33±0.01	0.34±0.01	0.34±0.01	0.33±0.01	0.33±0.01	0.33±0.02	0.33±0.01	0.33±0.01	0.33±0.01	0.33±0.01	0.32±0.01	0.33±0.01

b) Microwave

Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	36.02±0.7	36.38±0.3(a,c)	36.38±0.15(a,c)	36.56±0.26	36.64±0.11(a,c)	36.73±0.22	36.79±0.13	36.81±0.1	36.89±0.07	37.22±0.06	37.39±0.17	37.24±0.12	37.41±0.08
C12:0	0.33±0.17	0.39±0.26	0.44±0.34	0.27±0.01	0.35±0.12	0.38±0.23	0.43±0.33	0.46±0.24	0.34±0.17	0.42±0.18	0.36±0.18	0.36±0.17	0.36±0.16
C14:0	0.99±0.03	1±0.03	1±0.01	1.01±0.03	1±0.03	0.99±0.03	1±0.02	1±0.03	1±0.03	1.02±0.01	1.03±0.01	1.01±0.04	1.02±0.04
C16:0	3.68±0.07	3.68±0.07	3.68±0.07	3.71±0.07	3.71±0.06	3.72±0.06	3.74±0.05	3.75±0.04	3.75±0.04	3.77±0.07(a,c)	3.8±0.04(a,c)	3.8±0.04(a,c)	3.82±0.03(a,c)
C18:0	40.18±0.8	40.52±0.34	40.55±0.22	40.72±0.31	40.79±0.14	40.89±0.24	40.98±0.14	41.04±0.12	41.09±0.05	41.51±0.09	41.65±0.16(c)	41.52±0.13(c)	41.73±0.07(c)
C20:0	0.35±0.02	0.34±0.02	0.34±0.02	0.35±0.01	0.34±0.02	0.34±0.02	0.35±0.02	0.36±0.01	0.34±0.03	0.36±0.04	0.33±0.03	0.35±0.05	0.37±0.06
MUFA	45.25±0.34	45.21±0.25	45.14±0.24	45.34±0.39	45.24±0.31	45.26±0.31	45.24±0.28	45.24±0.33	45.34±0.24	45.09±0.24	45.15±0.19	45.11±0.16	45.18±0.11
C16:1	0.23±0.04	0.23±0.04	0.27±0.11	0.24±0.13	0.28±0.14	0.22±0.04	0.33±0.24	0.23±0.05	0.22±0.04	0.28±0.13	0.23±0.04	0.31±0.2	0.23±0.05
C18:1	45.64±0.37	45.6±0.29	45.57±0.3	45.75±0.39	45.68±0.39	45.65±0.34	45.73±0.42	45.63±0.37	45.73±0.28	45.58±0.25	45.59±0.18	45.64±0.12	45.63±0.09
C20:1	0.16±0.01	0.17±0.01	0.17±0.01	0.17±0.01	0.16±0.01	0.17±0.01	0.16±0.01	0.17±0.01	0.17±0.01	0.22±0.07	0.21±0.06	0.21±0.07	0.22±0.08
PUFA	12.09±0.12	12.05±0.07	11.95±0.06	11.83±0.07(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)	11.74±0.09(a,c)
C18:2 n6	12.45±0.1	12.4±0.06	12.3±0.06	12.17±0.07(a,c)	12.08±0.09(c)	11.99±0.16	11.84±0.05	11.77±0.15(a,c)	11.76±0.09(a,c)	11.34±0.05(a,c)	11.27±0.17(a,c)	11.34±0.16(a,c)	11.08±0.02(a,c)
C18:3 n6	0.36±0.02	0.36±0.02	0.35±0.02	0.35±0.02	0.34±0.01	0.33±0.02c	0.33±0.02(c)	0.33±0.02(c)	0.33±0.02(c)	0.33±0.02(c)	0.33±0.02(c)	0.33±0.02(c)	0.33±0.02(c)
C18:2 n6 / C16:0	0.34±0.01	0.33±0	0.33±0	0.32±0	0.32±0	0.32±0.01	0.31±0	0.31±0	0.31±0	0.3±0	0.29±0.01	0.3±0	0.29±0

Table 3 Continued.

c) Oven

Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	41.89±0.2(a,b)	41.96±0.17(b)	41.75±0.61(b)	41.7±0.51	41.99±0.33(b)	42.91±0.66	42.35±1.31	41.89±0.9	41.97±0.72	41.88±0.74	41.87±0.92	41.8±0.86	41.53±0.91
C12:0	0.26±0.03	0.27±0.01	0.42±0.31	0.26±0.01	0.5±0.27	0.62±0.23	0.54±0.31	0.46±0.23	0.43±0.22	0.33±0.14	0.43±0.39	0.48±0.26	0.35±0.18
C14:0	0.99±0.04	1.01±0.02	0.99±0.02	1.01±0.03	0.98±0.03	1.09±0.09	1.02±0.05	1.01±0.04	1±0.03	0.99±0.04	0.99±0.05	0.99±0.04	1±0.04
C16:0	36.49±0.08	36.56±0.2	36.17±0.33	36.29±0.43	36.35±0.12	37.29±1.05	36.55±0.85	36.25±0.53	36.37±0.42	36.37±0.58(b)	36.29±0.51(b)	36.12±0.49(b)	36.03±0.6(b)
C18:0	3.68±0.07	3.66±0.1	3.67±0.09	3.7±0.07	3.67±0.09	3.59±0.17	3.69±0.15	3.69±0.1	3.68±0.12	3.7±0.09	3.67±0.08(b)	3.69±0.07(b)	3.66±0.1(b)
C20:0	0.34±0.03	0.35±0.02	0.34±0.03	0.34±0.02	0.34±0.02	0.31±0.06	0.35±0.02	0.34±0.02	0.35±0.02	0.35±0.02	0.34±0.02	0.35±0.02	0.34±0.02
MUFA	45.65±0.17	45.63±0.15	45.69±0.37	45.84±0.43	45.65±0.34	44.66±0.78	45.28±0.98	45.6±0.57	45.73±0.6	45.81±0.62	45.8±0.76	45.89±0.63	45.81±0.38
C16:1	0.33±0.16	0.2±0.05	0.23±0.04	0.2±0.05	0.3±0.17	0.17±0.02	0.2±0.05	0.27±0.21	0.34±0.33	0.16±0.03	0.16±0.02	0.16±0.03	0.36±0.18
C18:1	45.16±0.03	45.26±0.18	45.31±0.34	45.48±0.44	45.2±0.24	44.33±0.74	44.93±0.99	45.16±0.56	45.22±0.6	45.49±0.66	45.49±0.8	45.56±0.67	45.29±0.23
C20:1	0.16±0.01	0.17±0.01	0.16±0.01	0.16±0.01	0.16±0.01	0.15±0.02	0.16±0.02	0.16±0.01	0.16±0.02	0.16±0.01	0.16±0.01	0.16±0.01	0.16±0.02
PUFA	12.43±0.03	12.41±0.05	12.46±0.09	12.47±0.11(b)	12.33±0.1(b)	12.35±0.07	12.2±0.3	12.32±0.14(b)	12.3±0.17(b)	12.32±0.14(b)	12.32±0.18(b)	12.32±0.29(b)	12.3±0.17(b)
C18:2 n6	12.07±0.03	12.05±0.04	12.11±0.11	12.12±0.12(b)	11.97±0.1(b)	11.97±0.06	11.85±0.31	11.97±0.16(b)	11.95±0.17(b)	11.97±0.15(b)	11.97±0.19(b)	11.98±0.3(b)	11.96±0.18(b)
C18:3 n6	0.36±0.02	0.36±0.02	0.36±0.02	0.36±0.02	0.36±0.02	0.39±0.02(a,b)	0.36±0.02(b)	0.35±0.02	0.36±0.02	0.36±0.02(b)	0.35±0.01(b)	0.35±0.02(b)	0.34±0.02(b)
C18:2 n6 / C16:0	0.33±0	0.33±0	0.33±0.01	0.33±0.01	0.33±0	0.32±0.01	0.32±0.02	0.33±0.01	0.33±0.01	0.33±0.01	0.33±0.01	0.33±0.01	0.33±0.01

ii) Palm olein

a) Deep fryer

Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	41.88±1.18	42.32±0.59	42.05±1.06	42.34±0.88	42.08±1.11	42.01±1.05	43.19±2.01	42.14±1.15	42.25±1.07	42.18±1.09	41.99±0.94	44.2±3.38	44.26±4.48
C12:0	0.16±0.05	0.2±0.01	0.35±0.27	0.42±0.29	0.34±0.21	0.19±0.01	0.79±0.87	0.32±0.29	0.36±0.34	0.31±0.27	0.19±0.01	1.95±2.03	0.19±0.01
C14:0	0.89±0.03	0.89±0.03	0.89±0.03	0.9±0.02	0.89±0.02	0.88±0.03(b)	1.75±1.72	0.9±0.04	0.9±0.04	0.9±0.03	0.9±0.03	0.86±0.03	3.7±3.25
C16:0	36.57±0.79	36.74±0.35	36.57±0.59	36.79±0.44	36.58±0.67	36.64±0.72	36.43±0.77	36.7±0.71	36.75±0.69	36.73±0.71	36.65±0.67	35.28±1.05(b,c)	35.42±1.79
C18:0	3.74±0.17	3.88±0.06	3.8±0.12	3.75±0.15	3.78±0.12	3.78±0.12	3.74±0.17	3.77±0.12	3.78±0.13	3.78±0.13	3.78±0.12	3.63±0.05	2.81±1.45b
C20:0	0.32±0.03	0.37±0.02	0.34±0.02	0.33±0.02	0.34±0.03	0.33±0.03	0.33±0.02	0.33±0.02	0.34±0.03	0.32±0.03	0.33±0.03	0.31±0.01	0.32±0.01
MUFA	45.87±0.94	45.38±0.27	45.88±0.87	45.75±0.86	45.88±0.97	45.91±0.97	45.11±1.74	45.82±1.01	45.76±0.92	46.05±1.13	46.02±0.87	44.51±2.97	43.69±2.98
C16:1	0.32±0.3	0.57±0.39	0.16±0.02	0.16±0.03	0.16±0.02	0.16±0.03	0.16±0.04b	0.16±0.03c	0.16±0.03	0.17±0.03	0.17±0.03	0.16±0.03	0.17±0.05
C18:1	45.39±0.84	44.66±0.19	45.57±0.9	45.45±0.89	45.56±1.01	45.6±1.02	44.81±1.78	45.5±1.05	45.46±0.96	45.74±1.17	45.71±0.92	44.21±3.01	43.38±3.02
C20:1	0.16±0.03	0.16±0.01	0.15±0.01	0.15±0.01	0.16±0.02	0.15±0.02	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.02	0.14±0.01	0.14±0
PUFA	11.83±0.26	11.68±0.39	11.79±0.15	11.71±0.23	11.78±0.18	11.8±0.24(c)	11.51±0.23	11.76±0.21	11.71±0.18(c)	11.59±0.41	11.72±0.23	11.12±0.27*	10.94±0.29*
C18:2 n6	11.54±0.29	11.46±0.37	11.52±0.26	11.47±0.28	11.51±0.25	11.51±0.28(c)	11.49±0.25	11.49±0.27	11.47±0.29	11.39±0.4	11.48±0.29	10.95±0.18	10.77±0.21
C18:3 n6	0.29±0.03	0.21±0.04	0.27±0.11	0.25±0.08	0.28±0.09	0.29±0.04	0.22±0.1	0.27±0.09	0.24±0.12	0.2±0.1	0.25±0.08	0.18±0.09	0.17±0.08
C18:2 n6 / C16:0	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01	0.25±0.01

Table 3 Continued.

b) Microwave													
Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	36.87±0.41	37.05±0.38	37.01±0.45	36.89±0.73	36.99±0.43	36.82±0.48	36.8±0.57	36.9±0.37	37.27±0.21	37.02±0.37	36.95±0.43	36.92±0.62	37.04±0.38
C12:0	0.18±0.02	0.39±0.24	0.19±0.01	0.19±0	0.43±0.29	0.45±0.31	0.32±0.29	0.35±0.33	0.29±0.24	0.32±0.26	0.34±0.29	0.33±0.33	0.49±0.35
C14:0	0.92±0.02	0.91±0.01	0.92±0.01	0.92±0.02	0.9±0.03	0.92±0.01(a)	0.92±0.02	0.9±0.02	0.92±0.01	0.92±0.02	0.92±0.01	0.9±0.03	0.93±0.01
C16:0	3.85±0.05	3.77±0.12	3.78±0.12	3.78±0.15	3.79±0.1	3.77±0.12	3.8±0.18	3.84±0.19	3.8±0.19	3.92±0.1	3.8±0.23	3.83±0.18(a)	3.84±0.17
C18:0	42.27±0.6	42.7±0.69	42.39±0.62	42.19±0.81	42.59±0.88	42.5±0.92	42.29±0.85	42.46±0.83	42.72±0.44	42.66±0.59	42.49±0.86	42.44±0.93	42.75±0.85(a)
C20:0	0.24±0.12	0.33±0.03	0.33±0.02	0.34±0.02	0.32±0.02	0.33±0.02	0.33±0.02	0.33±0.04	0.33±0.02	0.36±0.03	0.33±0.03	0.35±0.05	0.33±0.02
MUFA	45.35±0.49	44.96±0.56	45.38±0.67	45.35±0.52	45.22±0.81	45.27±0.78	45.4±0.65	45.36±0.73	45.38±0.63	45.26±0.55	45.22±0.55	45.45±0.83	45.27±0.79
C16:1	0.4±0.25	0.33±0.17	0.23±0.05	0.22±0.05	0.19±0.05	0.23±0.03	0.22±0.03(a,c)	0.26±0.11	0.28±0.14	0.27±0.11	0.3±0.14	0.19±0.05	0.22±0.04
C18:1	45.9±0.72	45.44±0.68	45.75±0.71	45.71±0.56	45.56±0.82	45.65±0.8	45.77±0.68	45.77±0.8	45.8±0.73	45.69±0.63	45.67±0.67	45.79±0.82	45.64±0.82
C20:1	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0	0.15±0.01	0.15±0.01(c)	0.15±0.01	0.15±0.01	0.16±0.01	0.15±0.01	0.15±0.01	0.16±0.01
PUFA	11.31±0.58	11.32±0.46	11.28±0.6	11.38±0.42	11.29±0.44	11.23±0.48	11.3±0.45	11.21±0.48	11.18±0.49	11.27±0.35	11.16±0.45	11.23±0.36	11.06±0.46
C18:2 n6	11.54±0.48	11.55±0.44	11.46±0.56	11.59±0.34	11.47±0.4	11.42±0.43	11.5±0.41	11.41±0.42	11.36±0.45	11.49±0.26	11.37±0.37	11.44±0.28	11.26±0.38
C18:3 n6	0.23±0.1	0.23±0.07	0.18±0.05	0.21±0.08	0.17±0.04	0.2±0.07	0.2±0.07	0.2±0.07	0.18±0.04	0.22±0.11	0.21±0.08	0.21±0.08	0.2±0.08
C18:2 n6 / C16:0	0.31±0.01	0.31±0.01	0.3±0.01	0.31±0.01	0.31±0.01	0.3±0.01	0.31±0.01	0.3±0.01	0.3±0.01	0.3±0.01	0.3±0.01	0.3±0.01	0.3±0.01

c) Oven													
Time (min)	0	15	30	45	60	75	90	105	120	135	150	165	180
SAFA	42.54±0.52	42.63±0.49	42.49±0.57	42.86±0.52	42.52±0.51	45.66±0.26	44.28±0.71	43.71±2.81	44.98±3.61	42.68±1.03	42.49±0.86	42.71±0.63	42.46±0.72
C12:0	0.34±0.23	0.17±0.04	0.19±0	0.27±0.17	0.19±0	1.35±1.34	1.22±2.07	0.84±1.31	1.62±1.66	0.39±0.24	0.28±0.18	0.18±0.04	0.3±0.21
C14:0	0.92±0.01	0.92±0.01	0.92±0.01	0.93±0.02	0.91±0.03	0.91±0.01	3.11±4.44	2.3±2.82	3.41±3.27	0.89±0.03	0.91±0.02	0.91±0.02	0.91±0.01
C16:0	36.97±0.24	37.27±0.3	37.1±0.4	37.25±0.29	37.12±0.28	38.75±2.32	35.43±2.28	36.18±1.73	35.49±1.73	37.01±0.52	37±0.5	37.27±0.26(a)	36.96±0.4
C18:0	3.77±0.13	3.73±0.17	3.76±0.12	3.8±0.09	3.78±0.12	3.56±0.16	3.67±0.19	3.7±0.12	3.64±0.06	3.79±0.14	3.81±0.1	3.8±0.1	3.79±0.13
C20:0	0.32±0.03	0.34±0.02	0.33±0.03	0.33±0.03	0.33±0.02	0.3±0.01	0.32±0.03	0.32±0.02	0.31±0.01	0.34±0.02	0.33±0.02	0.33±0.03	0.33±0.03
MUFA	45.63±0.76	45.55±0.59	45.67±0.68	45.51±0.73	45.8±0.72	43.13±3.87	44.24±3.80	44.73±2.36	43.87±3.15	45.56±1	45.75±0.89	45.9±1.11	45.77±0.73
C16:1	0.22±0.06	0.23±0.04	0.23±0.04	0.22±0.04	0.24±0.18	0.16±0.07	0.15±0.02(b)	0.41±0.14a	0.21±0.11	0.26±0.17	0.16±0.03	0.24±0.14	0.27±0.16
C18:1	45.25±0.73	45.17±0.56	45.3±0.65	45.14±0.7	45.41±0.68	42.82±3.84	43.96±3.82	44.18±2.39	43.52±3.1	45.15±0.95	45.45±0.93	45.53±1.07	45.36±0.73
C20:1	0.16±0.03	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.15±0.01	0.13±0.01b	0.14±0	0.14±0.01	0.15±0.01	0.14±0.01	0.14±0.01	0.15±0.01
PUFA	11.6±0.45	11.63±0.36	11.61±0.44	11.51±0.45	11.52±0.4	10.49±0.84(a)	11.21±0.77	11.32±0.42	10.98±0.35(a)	11.52±0.26	11.55±0.29	11.3±0.59	11.52±0.33
C18:2 n6	11.38±0.48	11.43±0.42	11.37±0.46	11.31±0.51	11.32±0.46	10.28±0.79(a)	10.99±0.74	11.09±0.45	10.79±0.29	11.31±0.35	11.34±0.36	11.16±0.58	11.29±0.39
C18:3 n6 / C18:2 n6	0.22±0.08	0.2±0.07	0.23±0.06	0.2±0.08	0.2±0.07	0.22±0.06	0.22±0.10	0.23±0.08	0.19±0.08	0.22±0.09	0.21±0.08	0.14±0.01	0.23±0.07
C16:0	0.31±0.01	0.31±0.01	0.31±0.01	0.3±0.01	0.31±0.01	0.27±0.04	0.31±0.01	0.31±0.01	0.3±0.01	0.31±0.01	0.31±0.01	0.3±0.01	0.31±0.01

Values are expressed as mean±SD (replicate analysis x 2 experiments). Data were measured by One-way Anova with Tukey posthoc multiple comparison tests to assess the differences between groups; * ($p < 0.05$) compared to 0 minutes within group. Mean values followed by different letters (a,b,c) are significant different ($p < 0.05$) between groups for different heating technique at same time point.

Table 4 Significant correlation coefficients of red palm olein on phytonutrients and physico-chemical analyses.

(a) Correlation coefficients between phytonutrients

Parameters			Alpha Tocotrienol			Gamma Tocotrienol			Alpha Tocopherol			Total Tocopherols			Tocols			Alpha Carotene			Beta Carotene			
Parameters	Method		a)	b)	c)	a)	b)	c)	a)	b)	c)	a)	b)	c)	a)	b)	c)	a)	b)	c)	a)	b)	c)	
Alpha Tocotrienol	Fryer	1	0.46	0.60	0.88	0.65	0.57	0.84	0.48	0.90	0.47	0.57	0.93	0.50	0.69	0.94	0.50	0.59	0.95	0.50	0.67	0.58	0.4	0.64
	Micro	0.46	1	0.95	0.33	0.89	0.90	0.83	0.99	0.40	0.99	0.94	0.71	0.97	0.88	0.52	1.00	0.88	0.52	0.99	0.96	0.95	0.99	0.88
	Oven	0.60	0.94	1	0.46	0.96	0.89	0.92	0.96	0.99	0.47	0.95	0.98	0.83	1.00	0.93	0.62	0.97	0.98	0.98	0.97	0.98	0.95	0.92
Delta Tocotrienol	Fryer	0.88	0.33	0.46	1	0.57	0.38	0.51	0.90	0.35	0.43	0.84	0.40	0.59	0.63	0.39	0.45	0.87	0.39	0.56	0.41	0.34	0.55	0.30
	Micro	0.65	0.89	0.95	0.57	0.37	0.91	0.86	0.90	0.54	0.90	0.96	0.86	0.90	0.93	0.69	0.93	0.96	0.93	0.92	0.94	0.88	0.85	
	Oven	0.57	0.84	0.83	0.92	0.74	0.94	0.86	0.91	0.38	0.89	0.97	0.77	0.90	0.89	0.53	0.90	0.97	0.90	0.92	0.95	0.88	0.93	
Gamma Tocotrienol	Fryer	0.84	0.35	0.43	0.88	0.93	0.85	0.92	0.71	0.84	0.90	0.98	0.97	0.87	0.92	0.84	0.86	0.91	0.96	0.93	0.91	0.82	0.91	0.85
	Micro	0.65	0.90	0.90	0.50	0.96	0.85	0.92	0.85	0.90	0.96	0.98	0.97	0.90	0.93	0.84	0.90	0.97	0.96	0.92	0.95	0.88	0.90	
	Oven	0.57	0.90	0.90	0.50	0.96	0.85	0.92	0.85	0.90	0.96	0.98	0.97	0.90	0.93	0.84	0.90	0.97	0.96	0.92	0.95	0.88	0.90	
Alpha Tocopherol	Fryer	0.90	0.40	0.47	0.90	0.54	0.38	0.71	0.40	0.91	0.41	0.42	0.82	0.42	0.58	0.98	0.43	0.44	0.86	0.43	0.55	0.41	0.38	0.52
	Micro	0.47	0.99	0.954	0.35	0.90	0.89	0.91	0.41	1	0.95	0.73	1.00	0.89	0.89	0.53	1.00	0.95	0.70	1.00	0.92	0.96	1.00	0.99
	Oven	0.57	0.94	0.98	0.43	0.96	0.97	0.90	0.42	0.95	1	0.80	0.97	0.91	0.89	0.58	0.96	0.99	0.77	0.97	0.95	0.98	0.94	
Total Tocopherols	Fryer	0.93	0.71	0.83	0.84	0.86	0.77	0.98	0.74	0.85	0.82	0.73	0.80	1	0.75	0.86	0.92	0.75	0.81	0.77	0.75	0.86	0.81	0.67
	Micro	0.50	0.99	0.97	0.40	0.93	0.90	0.93	0.42	0.99	0.97	0.97	0.75	1	0.90	0.86	1.00	0.96	0.73	1.00	0.93	0.96	0.95	
	Oven	0.69	0.88	0.93	0.59	0.90	0.89	0.92	0.59	0.89	0.93	0.92	0.75	0.80	0.90	0.86	0.90	0.92	0.85	0.90	0.92	0.96	0.99	
Total Tocopherols	Fryer	0.50	0.99	0.97	0.39	0.93	0.90	0.86	0.90	0.92	0.43	0.90	0.96	0.75	0.86	0.96	0.86	1.00	0.93	0.85	0.90	0.92	0.96	0.92
	Micro	0.50	0.99	0.97	0.39	0.93	0.90	0.86	0.90	0.92	0.43	0.90	0.96	0.75	0.86	0.96	0.86	1.00	0.93	0.85	0.90	0.92	0.96	
	Oven	0.59	0.94	0.98	0.45	0.96	0.97	0.91	0.96	0.97	0.44	0.93	0.99	0.81	0.96	0.92	0.99	0.96	0.73	1.00	0.93	0.96	0.95	
Tocols	Fryer	0.95	0.69	0.80	0.79	0.83	0.74	0.96	0.71	0.83	0.86	0.70	0.77	0.99	0.73	0.85	0.95	0.73	0.78	1	0.78	0.96	0.95	0.91
	Micro	0.50	0.99	0.97	0.39	0.93	0.90	0.86	0.99	0.93	0.90	0.97	0.75	1.00	0.89	0.56	1.00	0.96	0.73	0.73	0.84	0.78	0.67	
	Oven	0.67	0.91	0.96	0.56	0.93	0.92	0.93	0.92	0.97	0.55	0.92	0.95	0.86	0.93	1.00	0.99	0.93	0.85	1	0.95	0.99	0.98	
Alpha Carotene	Fryer	0.58	0.95	0.94	0.94	0.94	0.95	0.91	0.96	0.96	0.41	0.96	0.98	0.81	0.96	0.92	0.57	0.97	0.88	0.78	0.96	0.95	0.91	
	Micro	0.43	0.99	0.94	0.34	0.88	0.86	0.87	0.89	0.89	0.38	0.97	0.94	0.69	0.99	0.88	0.91	0.99	0.93	0.67	0.94	0.90	0.88	
	Oven	0.66	0.91	0.98	0.55	0.98	0.92	0.94	0.96	0.53	0.93	0.97	0.97	0.85	0.96	0.97	0.96	0.97	0.93	0.85	0.95	0.97	0.93	
Beta Carotene	Fryer	0.41	0.99	0.92	0.30	0.85	0.85	0.87	0.80	0.88	0.36	0.99	0.97	0.67	0.98	0.86	0.48	0.99	0.91	0.65	0.89	0.93	0.81	
	Micro	0.41	0.99	0.92	0.30	0.85	0.85	0.87	0.80	0.88	0.36	0.99	0.97	0.67	0.98	0.86	0.48	0.99	0.91	0.65	0.89	0.93	0.81	
	Oven	0.64	0.89	0.93	0.51	0.92	0.97	0.93	0.91	0.98	0.52	0.90	0.95	0.87	0.92	0.92	0.66	0.92	0.85	0.83	0.92	0.94	0.87	

(b) Correlation coefficients between physico-chemical analyses

Parameters			PV			AnV			TOTOX			FFA		
Parameters	Method		a)	b)	c)	a)	b)	c)	a)	b)	c)	a)	b)	c)
PV	Fryer	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Micro	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Oven	0.95	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
AnV	Fryer	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Micro	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Oven	0.95	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
TOTOX	Fryer	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Micro	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Oven	0.95	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
FFA	Fryer	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Micro	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Oven	0.95	0.95	1	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

(c) Correlation coefficients between phytonutrients and physico-chemical analyses

Parameters			Alpha tocotrienol						Gamma Tocotrienol						Alpha Tocopherol						Total Tocotrienols						Tocols						Alpha Carotene						Beta Carotene																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Parameters	Method		a)	b)	c)	Fryer	Micro	Oven	a)	b)	c)	Fryer	Micro	Oven	a)	b)	c)	Fryer	Micro	Oven	a)	b)	c)	Fryer	Micro	Oven	a)	b)	c)	Fryer	Micro	Oven	a)	b)	c)	Fryer	Micro	Oven																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
PV	a) Fryer		0.64	0.97	0.88	0.44	0.88	0.92	0.91	0.89	0.92	0.46	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97	0.94	0.83	0.97

Table 5 Significant correlation coefficients of palm olein on phytonutrients and physico-chemical analyses.

(a) Correlation coefficients between phytonutrients

Parameters		Alpha tocotrienol			Delta tocotrienol			Gamma tocotrienol			Alpha Tocopherol			Total Tocotrienols			Total Tocopherols			Tocols		
Parameters	Method	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven
Alpha tocotrienol	a) Fryer	1	0.37	0.36	0.91*	0.28	0.56*	0.90*	0.90*	0.42	0.92*	0.51	0.41	0.96*	0.29	0.41	0.92*	0.04	0.97*	0.99*	0.33	0.41
	b) Micro	0.37	1	0.92*	0.53	0.98*	0.62*	0.71*	0.97*	0.83*	0.92*	0.97*	0.92*	0.58*	0.99*	0.89*	0.04	0.97*	0.91*	0.49	0.99*	0.89*
	c) Oven	0.36	0.92*	1	0.59*	0.95*	0.75*	0.72*	0.96*	0.97*	0.03	0.83*	1.00*	0.59*	0.95*	0.99*	0.04	0.83*	1.00*	0.50	0.94*	0.99*
Delta	a) Fryer	0.91*	0.53	0.59*	1	0.45	0.75*	0.94*	0.72*	0.97*	0.77*	0.60*	0.64*	0.97*	0.48	0.64*	0.78*	0.59*	0.64*	0.96*	0.50	0.64*
	b) Micro	0.28	0.98*	0.95*	0.45	1	0.59*	0.64*	0.99*	0.84*	-0.08	0.90*	0.93*	0.50	1.00*	0.90*	-0.08	0.91*	0.93*	0.40	0.99*	0.91*
	c) Oven	0.56*	0.62*	0.75*	0.73*	0.59*	0.74*	1	0.74*	0.99*	0.36	0.60*	0.76*	0.69*	0.61*	0.85*	0.35	0.60*	0.78*	0.64*	0.61*	0.83*
Gamma	a) Fryer	0.90*	0.56*	0.72*	0.94*	0.64*	0.74*	1	0.63*	0.86*	0.68*	0.77*	0.95*	0.49	1.00*	0.91*	0.69*	0.77*	0.76*	0.96*	0.68*	0.75*
	b) Micro	0.25	0.97*	0.72*	0.44	0.99*	0.60*	0.63*	1	0.86*	-0.11	0.89*	0.95*	0.49	1.00*	0.85*	-0.11	0.89*	0.94*	0.38	0.99*	0.92*
	c) Oven	0.42	0.83*	0.96*	0.66*	0.84*	0.90*	0.74*	0.63*	1	0.13	0.19	0.083	0.80*	-0.06	0.10	1.00*	0.76*	0.97*	0.55	0.85*	0.99*
Alpha	a) Fryer	0.92*	0.03	0.03	0.77*	-0.08	0.36	0.68*	0.74*	0.13	1	0.19	0.083	0.80*	-0.06	0.10	1.00*	0.18	0.08	0.86*	-0.03	0.09
	b) Micro	0.51	0.97*	0.83*	0.60*	0.90*	0.60*	0.77*	0.88*	0.76*	0.19	1	0.83*	0.68*	0.92*	0.80*	0.20	1.00*	0.85*	0.60*	0.94*	0.81*
	c) Oven	0.41	0.92*	1.00*	0.64*	0.93*	0.78*	0.76*	0.95*	0.96*	0.08	0.83*	1	0.64*	0.94*	0.99*	0.09	0.83*	1.00*	0.55	0.93*	0.99*
Total Tocotrienols	a) Fryer	0.96*	0.58*	0.59*	0.97*	0.50	0.69*	0.99*	0.66*	0.85*	-0.06	0.92*	0.94*	0.52	0.91*	0.91*	-0.06	0.92*	0.94*	0.89*	0.55	0.63*
	b) Micro	0.29	0.99*	0.95*	0.48	1.00*	0.61*	0.66*	0.99*	0.85*	0.83*	0.92*	0.64*	0.63	0.91*	1	0.1	0.81*	0.99*	0.42	1.00*	0.92*
	c) Oven	0.41	0.89*	0.99*	0.64*	0.90*	0.85*	0.75*	0.91*	0.99*	0.10	0.80*	0.99*	0.63	0.91*	1	0.1	0.81*	0.99*	0.55	0.90*	1.00*
Total Tocopherols	a) Fryer	0.92	0.04	0.04	0.78	-0.08	0.35	0.70*	0.77*	0.13	0.99*	0.20	0.09	0.80*	-0.06	0.01	1	0.19	0.09	0.87*	-0.02	0.10
	b) Micro	0.50	0.97*	0.83*	0.60*	0.91*	0.60*	0.77*	0.89*	0.76*	0.18	1.00*	0.83*	0.67*	0.92*	0.81*	0.19	1	0.83*	0.59*	0.94*	0.81*
	c) Oven	0.41	0.91*	1.00*	0.64*	0.93*	0.78*	0.76*	0.94*	0.97*	0.08	0.83*	1.00*	0.64*	0.94*	0.99*	0.09	0.83*	1	0.55	0.93*	1.00*
Tocols	a) Fryer	0.99*	0.49	0.50	0.96*	0.40	0.64*	0.96*	0.96*	0.55	0.86*	0.60*	0.55	0.99*	0.42	0.55	0.87*	0.60*	0.55	1	0.45	0.55
	b) Micro	0.32	1.00*	0.94*	0.50	0.99*	0.61*	0.68*	0.99*	0.85*	-0.03	0.94*	0.93*	0.55	0.99*	0.90*	-0.02	0.84*	0.93*	0.94*	1	0.91*
	c) Oven	0.41	0.89*	0.99*	0.64*	0.91*	0.83*	0.75*	0.92*	0.99*	0.09	0.81*	0.99*	0.63*	0.92*	1.00*	0.10	0.81*	1.00*	0.55	0.91*	1

(b) Correlation coefficients between physico-chemical analyses

Parameters		PV			AnV			TOTOX			FFA		
Parameters	Method	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven
PV	a) Fryer	1	0.76*	0.68*	0.48	0.76*	0.62*	0.69*	0.7*	0.70*	0.79*	0.98*	0.88*
	b) Micro	0.68*	1	0.97**	0.75*	0.75*	0.85*	0.85*	0.94*	0.97*	0.98*	0.97*	0.97*
	c) Oven	0.48	0.97**	1	0.75*	0.88*	0.85*	0.82*	0.95*	1.00*	0.97*	0.97*	0.92*
AnV	a) Fryer	0.68*	0.75*	0.75*	1	0.88*	0.85*	0.85*	0.84*	0.77*	0.81*	0.74*	0.85*
	b) Micro	0.75*	0.85*	0.88*	0.85*	1	0.88*	0.88*	0.84*	0.90*	0.98*	0.85*	0.94*
	c) Oven	0.73*	0.85*	0.97*	0.85*	0.85*	0.85*	0.87*	0.98*	0.99*	0.98*	0.87*	0.94*
TOTOX	a) Fryer	0.69*	0.85*	0.82*	0.80*	0.94*	0.88*	0.90*	0.96*	0.96*	0.97*	0.97*	0.92*
	b) Micro	0.69*	0.85*	0.95*	0.84*	0.94*	0.94*	1	0.96*	1	0.98*	0.94*	0.94*
	c) Oven	0.70*	0.98*	1.00*	0.77*	0.98*	0.99*	0.90*	0.96*	0.90*	0.90*	0.94*	0.82*
FFA	a) Fryer	0.56*	0.83*	0.88*	0.82*	0.90*	0.99*	0.84*	0.97*	0.98*	1	0.98*	0.99*
	b) Micro	0.79*	0.98*	0.97*	0.81*	0.91*	0.91*	0.90*	0.97*	0.98*	0.90*	0.82*	0.99*
	c) Oven	0.88*	0.97*	0.92*	0.74*	0.85*	0.85*	0.87*	0.92*	0.94*	0.82*	0.99*	1

Table 5 Continued.
(c) Correlation coefficients between phytonutrients and physico-chemical analyses

Parameters		Alpha tocotrienol			Delta Tocotrienol			Gamma Tocotrienol			Alpha Tocopherol			Total Tocotrienols			Total Tocopherols			Tocols		
Parameters	Method	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven	a) Fryer	b) Micro	c) Oven
PV	a) Fryer	-0.05	-0.61*	-0.74*	-0.35	-0.67*	-0.63*	-0.37	-0.69*	-0.78*	0.186	-0.52	-0.73*	-0.26	-0.66*	-0.76*	0.18	-0.52	-0.74*	-0.18	-0.65*	-0.76*
	b) Micro	-0.05	-0.86*	-0.91*	-0.29	-0.91*	-0.63*	-0.45	-0.93*	-0.85*	0.278	-0.74*	-0.89*	-0.3	-0.91*	-0.88*	0.278	-0.75*	-0.89*	-0.19	-0.9*	-0.89*
	c) Oven	-0.01	-0.88*	-0.9*	-0.25	-0.92*	-0.53*	-0.42	-0.94*	-0.81*	0.299	-0.74*	-0.87*	-0.26	-0.92*	-0.86*	0.296	-0.75*	-0.87*	-0.16	-0.91*	-0.86*
AnV	a) Fryer	-0.62*	-0.88*	-0.89*	-0.72*	-0.83*	-0.76*	-0.87*	-0.84*	-0.88*	-0.33	-0.87*	-0.9*	-0.78*	-0.86*	-0.9*	-0.34	-0.87*	-0.9*	-0.72*	-0.87*	-0.9*
	b) Micro	-0.32	-0.95*	-0.94*	-0.52*	-0.95*	-0.53*	-0.68*	-0.97*	-0.82*	0.037	-0.87*	-0.93*	-0.55	-0.97*	-0.88*	0.02	-0.87*	-0.93*	-0.45	-0.96*	-0.89*
	c) Oven	-0.15	-0.91*	-0.97*	-0.41*	-0.95*	-0.62*	-0.56*	-0.97*	-0.89*	0.192	-0.78*	-0.95*	-0.4	-0.96*	-0.93*	0.185	-0.78*	-0.95*	-0.3	-0.94*	-0.94*
TOTOX	a) Fryer	-0.52	-0.91*	-0.95*	-0.7	-0.89*	-0.82*	-0.82*	-0.9	-0.95*	-0.22	-0.87*	-0.96*	-0.72	-0.91*	-0.97*	-0.23	-0.87*	-0.96*	-0.64*	-0.91*	-0.97*
	b) Micro	-0.23	-0.95*	-0.96*	-0.45	-0.97*	-0.58*	-0.62*	-0.99*	-0.86*	0.128	-0.85*	-0.95*	-0.48	-0.98*	-0.91*	0.117	-0.86*	-0.95*	-0.37	-0.97*	-0.92*
	c) Oven	-0.06	-0.89*	-0.93*	-0.31	-0.93*	-0.57*	-0.47	-0.96*	-0.84*	0.266	-0.76*	-0.91*	-0.31	-0.94*	-0.85*	0.261	-0.77*	-0.9*	-0.21	-0.93*	-0.89*
FFA	a) Fryer	-0.27	-0.96*	-0.92*	-0.45	-0.96*	-0.49	-0.64*	-0.97*	-0.78*	0.083	-0.87*	-0.91*	-0.5	-0.97*	-0.88*	0.068	-0.88*	-0.9*	-0.4	-0.97*	-0.87*
	b) Micro	-0.16	-0.91*	-0.96*	-0.4	-0.95*	-0.64*	-0.56*	-0.97*	-0.89*	0.179	-0.79*	-0.94*	-0.41	-0.95*	-0.93*	0.174	-0.8*	-0.94*	-0.3	-0.94*	-0.94*
	c) Oven	-0.11	-0.85*	-0.93*	-0.37	-0.89*	-0.68*	-0.51*	-0.92*	-0.9*	0.209	-0.74*	-0.91*	-0.36	-0.9*	-0.91*	0.204	-0.75*	-0.91*	-0.26	-0.89*	-0.91*

Correlation significance at P=0.05 is indicated by an asterisk (*)
Fryer deep fryer, micro microwave

Indicator	Positive	Negative
weak		
moderate		
strong		

Author Contributions

R.L., K-T.T. and A.H.A.T. were involved in project conceptualization and design. R.L. and K-T.T. conducted the research and statistical analysis; prepared the manuscript and had primary responsibility for the content; and contributed for laboratory and data analyses. A.H.A.T. contributed to laboratory and data analyses, as well as manuscript editing. S.R.V edited the manuscript. All authors read and approved the manuscript.

Funding

This work was supported by research grants from the Malaysian Palm Oil Board (Project ID: PD16412).

Declaration of Interest

The authors have no relevant interests to declare.

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