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Effect of microwave heating with different exposure times on the degradation of corn oil

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Abstract

In the present work, the influence of microwave power and heating times on the quality degradation of corn oil was evaluated. Microwave heating test was carried out using a domestic microwave oven for different periods at low- and medium-power settings for the corn oil sample. The changes in physicochemical characteristics related to oil degradation of the samples during heating were determined by standard methods. In this study, refractive index, free fatty acid content, peroxide value, p-anisidine value, TOTOX value, viscosity and total polar compound of the oils all increased with increasing heating power and time of exposure. In GLC analysis, the percentage of linoleic acid tended to decrease, whereas the percentage of palmitic, stearic and oleic acids increased. The C18:2/C16:0 ratio decreased in all oil samples with increasing heating times. Exposing the corn oil to various microwave power settings and heating periods caused the formation of hydroperoxides and secondary oxidation products. The heating reduced the various tocopherol isomers in corn oil and highest reduction was detected in γ-tocopherol. Longer microwave heating times resulted in a greater degree of oil deterioration. Microwave heating caused the formation of comparatively lower amounts of some degradative products in the oil samples heated at low-power setting compared to medium-power setting. The present analysis indicated that oil quality was affected by both microwave power and heating time.

Introduction

The modern way of life obliges individuals to reduce the time dedicated to prepare meals to the minimum possible. Under such circumstances, microwave oven is increasingly an indispensable utensil in modern kitchens due to its. This equipment which has the capacity to rapidly transmit heat due to microwaves high penetration power, is easy to use, and allow to reduce time, effort and energy comparatively to conventional culinary methods (Malheiro *et al.* 2009). Several reports highlight vegetable oils quality degradation, reduction in bioactive compounds, fatty acids degradation, color modifications, as well as physical and rheological changes. Malheiro *et al*. (2009) studied the effect of different microwave heating times on characteristics of three Portuguese olive oils and concluded that microwave heating produced significant losses in olive oil quality and in their nutritional value. The extension of losses was higher when the time of exposure increases. Mishra *et al*. (2011) evaluated the oxidative stability of rice bran oil in an oven test and the microwave heating in the different dosages of antioxidants. The study concluded that microwave heating time was associated with the absorptivity and this analysis might be adopted to compare the oxidative analysis of oils under microwave heating. Kreps *et al.* (2014) investigated the influence of microwave heating on sunflower and corn oils using two types of ovens. The samples were heated for 90% and 70% of the total heating time and the remaining time was dissipation pause. It was proved that the peroxide values, rate constant of tocopherol degradation and decrease of tocopherol content during heating of oils in second oven was almost two times lower than in oils heated with the first oven. Sengar *et al.* (2015) selected a blend of hydrogenated palm kernel oil and butter and exposed the samples to microwave heating at low and high power settings. The treated samples were analyzed for physico-chemical properties and found to increase in fat/ oil oxidation with increasing microwave treatment time and power.

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Corn oil is widely used in all purposes as cooking oil and for margarine because of its unique flavor attributes and because it is more stable to oxidation than linolenate containing oils, such as soybean or canola (Warner and Nelsen, 1996). Meanwhile, it was feasible to predict the formation of the harmful compounds arising from heating effect of microwave heating. Consequently, this work was devoted to study the effect of microwave heating on the quality degradation of corn oil.

Materials and Methods

Materials

Refined corn oil (Sime Darby Food and Beverages, Malaysia) was purchased from local super market. The oil was kept in the refrigerator below 4^0C for storage. All chemicals and solvents used were of analytical grade. p-Anisidine and silica gel were products of Merck (Darmstadt, Germany). Standards of fatty acid methyl esters were purchased from Supelco Chemical Co. (Bellefonte, PA, USA). All other chemicals and solvents were from J.T. Baker (Phillipsburg, USA) or RCI Labscan Ltd. (Pathumwan, Thailand).

Microwave heating operation

The oil samples (100 ml) were weighted into beakers which were put at equal distances on the turntable plate of the microwave oven (Model NN-ST65IM, Panasonic Co. Ltd., China). The samples were heated at low- and medium-power settings, for different periods (2, 4, 8, 12, 16 and 20 min). The final oil temperatures at various heating times were recorded by inserting a calibrated thermocouple (Model HI 9043, Hanna Instruments Ltd., Bedfordshire, UK) into the oil immediately after removal from the oven. Some additional steps were carried out between tests due to standardize the operation for each heating operation. The oven door was opened for sufficient times to facilitate the cooling process; so that the temperature of the oven was reduced to normal room temperature between the tests. Finally, all samples were stored at -16°C for further analyses.

Fatty acids composition

Fatty acids of the oil samples were converted to their corresponding methyl esters following PORIM (PORIM, 1995) test method p3.4 prior to analysis by gas-liquid chromatography. Fatty acids composition was analyzed using an auto-system XL gas chromatograph (Perkin Elmer Incorporate, Massachusetts, USA) equipped with a SP-2340 (Supelco Inc., Bellefonte, PA, USA) fused silica capillary column (60 m x 0.25 mm i.d x 0.20 µm film thickness) and a flame ionization detector. Carrier gas was nitrogen with a flow rate of 20 ml/min at 20 psi. Initial oven temperature was set to 100°C, raised to 170°C at 20 °C/min, then programmed to 230°C at 10 °C/min, hold at 230°C for 7 min, and finally heated to 250°C at 30 °C/min. The detector and injector temperatures were both maintained at 250°C. Methyl esters were quantified by comparing the retention times and peak area of the unknowns with known FAME standard mixtures.

Standard physicochemical analyses

Refractive index (method Cc 7-25), free fatty acid content (method Ca 5a-40) and peroxide value (method Cd 8-53) were determined according to American Oil Chemists' Society official methods (AOCS, 1987). p-Anisidine value (method p2.4) of the samples were evaluated by means of a Jenway 6305 Spectrophotometer (Barloworld Scientific Ltd., UK) following the PORIM (PORIM, 1995) test method. Total oxidation (TOTOX) value was calculated using the expression: TOTOX = 2PV+ p-AV (Shahidi and Wanasundara, 2002).

Viscosity measurement

Viscosity of the oil was measured by using a Brookfield LVDV–II+P viscometer (Brookfield Engineering Laboratories Inc., Middleboro, USA). One milliliter of oil was put on the plate of the viscometer with spindle CPE-42; the viscosity of the sample was read in cP (centipoises) directly from the viscometer, which was maintained at 30°C and 40°C.

Polar compounds

The total polar compound contents were estimated by the mini column method (Dobarganes *et al*., 2000). One gram of oil was dissolved in light petroleum ether/diethyl ether (90:10, v/v) and made up to 10 mL with the same solvent mixture. Five milliliters of the solution were introduced onto a silica gel (Merck grade 60, 70-230 mesh) column. The nonpolar fraction was eluted with 60 mL of light petroleum ether/diethyl ether (90:10, v/v) while the polar fraction was eluted with 50 mL of diethyl ether. The solvent was evaporated by rotary evaporator and the completeness of fractionation was examined by thin-layer chromatography using an elution system, light petroleum ether: diethyl ether: acetic acid (70:40:1; v:v:v).

Tocopherol analysis

Tocopherol composition of the samples was

Table 1. Fatty acid composition (%) of corn oil during microwave heating

Power setting	Time (min)	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	*Trans* $C_{18:2}$	$C_{18:3}$	$C_{20:0}$	SFA	MUFA	PUFA	C18:2/ C16:0
	0	0.03 ± 0.00	0.05 ± 0.00	11.13 ± 0.05	0.11 ± 0.00	2.10 ± 0.00	29.51 ± 0.15	55.08 ± 0.09	0.60 ± 0.01	0.23 ± 0.00	1.18 ± 0.00	14.49	29.62	55.91	5.00
Low	2	0.04 ± 0.00	0.05 ± 0.00	11.23 ± 0.18	0.11 ± 0.00	2.15 ± 0.03	29.68 ± 0.02	54.74 ± 0.22	0.59 ± 0.00	0.23 ± 0.00	1.18 ± 0.01	14.65	29.79	55.56	4.92
	4	0.04 ± 0.00	0.05 ± 0.00	11.01 ± 0.02	0.10 ± 0.00	2.10 ± 0.03	29.55 ± 0.20	55.13 ± 0.25	0.61 ± 0.04	0.22 ± 0.00	1.19 ± 0.00	14.39	29.65	55.96	5.06
	8	0.03 ± 0.00	0.05 ± 0.00	11.05 ± 0.03	0.10 ± 0.00	2.12 ± 0.02	29.69 ± 0.03	54.90 ± 0.05	0.62 ± 0.02	0.23 ± 0.01	1.20 ± 0.00	14.45	29.79	55.75	5.02
	12	0.03 ± 0.00	0.05 ± 0.00	11.04 ± 0.03	0.10 ± 0.00	2.09 ± 0.03	29.71 ± 0.01	54.90 ± 0.00	0.63 ± 0.03	0.25± 0.03	1.18 ± 0.00	14.39	29.81	55.78	5.02
	16	0.03 ± 0.00	0.05 ± 0.00	11.10 ± 0.04	0.10 ± 0.00	2.16 ± 0.04	29.87 ± 0.13	54.44 ± 0.32	0.56 ± 0.04	0.27 ± 0.04	1.19 ± 0.00	14.53	29.97	55.27	4.95
	20	0.03 ± 0.00	0.05 ± 0.00	11.26 ± 0.03	0.11 ± 0.00	2.14 ± 0.01	29.87 ± 0.18	54.37 ± 0.00	0.58 ± 0.05	0.22 ± 0.00	1.16 ± 0.02	14.64	29.98	55.17	4.88
	0	0.03 ± 0.00	0.05 ± 0.00	11.13 ± 0.05	0.11 ± 0.00	2.10 ± 0.00	29.51 ± 0.15	55.08 ± 0.09	0.60 ± 0.01	0.23 ± 0.00	1.18 ± 0.00	14.49	29.62	55.91	5.00
	2	0.03 ± 0.00	0.05 ± 0.00	11.04 ± 0.06	0.10 ± 0.00	2.14 ± 0.00	29.78 ± 0.00	54.82 ± 0.08	0.61 ± 0.00	0.23 ± 0.00	1.18 ± 0.01	14.44	29.88	55.66	5.02
	4	0.03 ± 0.00	0.05 ± 0.00	11.34 ± 0.11	0.10 ± 0.00	2.18 ± 0.06	30.16 ± 0.17	54.08 ± 0.27	0.69 ± 0.05	0.23 ± 0.00	1.14 ± 0.02	14.74	30.26	55.00	4.83
Medium	8	0.03 ± 0.00	0.05 ± 0.00	11.22 ± 0.01	0.11 ± 0.00	2.13 ± 0.00	29.87 ± 0.09	54.49 ± 0.11	0.70 ± 0.00	0.22 ± 0.00	1.16 ± 0.00	14.59	29.98	55.41	4.92
	12	0.03 ± 0.00	0.07 ± 0.02	11.55 ± 0.03	0.15 ± 0.04	2.23 ± 0.03	30.69 ± 0.16	53.06 ± 0.37	0.98 ± 0.03	0.25 ± 0.00	1.04 ± 0.00	14.92	30.84	54.29	4.68
	16	0.04 ± 0.00	0.06 ± 0.00	12.13 ± 0.07	0.11 ± 0.00	2.32 ± 0.02	31.33 ± 0.20	52.75 ± 0.53	1.34 ± 0.64	0.26 ± 0.00	0.82 ± 0.00	15.37	31.44	54.35	4.46
	20	0.04 ± 0.00	0.06 ± 0.00	12.59 ± 0.07	0.11 ± 0.00	2.45 ± 0.01	32.33 ± 0.20	46.36 ± 1.13	2.56 ± 0.25	0.28 ± 0.00	0.64 ± 0.03	15.78	32.44	49.20	3.88

Each value in the table represents the mean of two replicates ± SD.

determined using HPLC (Agilent 1100 series, Agilent Technologies, Wilmington, USA) according to the AOCS (AOCS, 1987) Official Method Ce 8-89. Briefly, oil sample was dissolved with n-hexane (Merck, Darmstadt, Germany) before being injected into the HPLC. The HPLC was fitted with a 250×4 mm column, packed with 5 µm of silica (Jones chromatography). A fluorescence detector (Agilent Model G1321A, Massachusetts, USA) was set at 292 and 330 nm for excitation and emission wavelengths, respectively. Mobile phase consisted of iso-propanol (Merck, Darmstadt, Germany) in n-hexane (0.5:99.5, v/v) with a flow rate of 1.4 ml/min. Tocopherols were determined by comparing their retention times with those of standard ones. Separate calibration curves for alpha, beta, delta and gamma tocopherol standards (Sime Darby Research Sdn. Bhd., Malaysia) were made for their quantification in the samples.

Statistical analysis

All data were expressed as the mean and standard deviation (SD). The data from the standard physicochemical analyses, viscosity and polar compounds were subjected to one way analysis of variance (ANOVA) and mean values were compared at $P<0.05$ significant level by Duncan's multiple range test using SPSS 11.5 software package.

Results and Discussion

Fatty acids composition of the samples is presented in Table 1. Fresh corn oil was characterized by a high content of linoleic acid (55.08%) followed by oleic acid (29.51%), palmitic acid (11.13%) and stearic acid at lesser concentration (2.10%). A high content of linoleic acid detected in the fresh corn oil makes it more susceptible to the oxidative deterioration. Still, microwave heating inflicted changes in fatty acids profile of both oils. Analyzing the fatty acids by their common nature, grouped according to their unsaturation degree of the hydrocarbon chain, the most affected fraction was the PUFA, directly related with their higher number of double bonds, with higher susceptibility to oxidation (Martins-Polvillo *et al*., 2004; Choe and Min, 2006). In this study, the percentage of linoleic acid tended to decrease, whereas the percentages of palmitic, stearic and oleic acids, increased, probably due to PUFA degradation. Before heating, corn oil contained trans C18:2 (0.60%). Trans isomers in the fresh oils are supposed to be produced in the deodorization process of crude oils (Tsuzuki *et al*., 2010). Trans C18:2 was found to increase with increasing heating times. In the present study, in most case the changes in fatty acid composition were not remarkable. C18:2/C16:0 ratios in microwave heated oils are shown in Table 1. The ratio was expected to decrease due to a decline in linoleic acid by oxidation. It was considered to be a reliable indicator of lipid oxidation during the heating process. A decrease in the relative percentage of unsaturated fatty acids and an increase in the relative percentage of saturated fatty acids occur when the oils are heated (Tan and Che Man, 1999). Our results revealed this ratio decreased in all oil samples during the heating process. The decreased amount from the initial in the ratio C18:2/C16:0 for the lower power setting (0.12 unit) was significantly lower than that observed for medium power setting (1.12 units). Moreover, the alteration in the percentage of fatty acids as the result of the heat effect at low power setting was lower compared to those generated at medium power setting.

Table 2. Refractive index, free fatty acid value and viscosity of corn oil during microwave heating

Power setting	Heating time (min)	Refractive index (25°C)	Free fatty acid (%)	Viscosity (cP)	
				at 30°C	at 40°C
Low	0	1.4720 ± 0.00^{a}	0.15 ± 0.02^{a}	43.20 ± 0.74^{a}	26.41 ± 0.16^{a}
	2	1.4720 ± 0.00^{a}	0.17 ± 0.02^{a}	43.20 ± 0.74^{a}	26.41 ± 0.16^{a}
	4	1.4720 ± 0.00^{a}	0.20 ± 0.00^{b}	43.51 ± 0.51^{a}	26.49 ± 0.83^{a}
	8	1.4721 ± 0.00^{a}	0.21 ± 0.00^{b}	44.03 ± 0.08^{ab}	27.77 ± 0.34^{b}
	12	1.4722 ± 0.00^{b}	0.21 ± 0.00^{b}	44.85 ± 0.28^{bc}	28.45 ± 0.43^{b}
	16	1.4723 ± 0.00^{c}	0.21 ± 0.00^{b}	45.59 ± 0.22^{c}	29.87 ± 0.27^{c}
	20	1.4723 ± 0.00^{c}	0.22 ± 0.01^{b}	45.73 ± 0.43^{c}	31.04 ± 0.52^{d}
Medium	0	1.4720 ± 0.00^{a}	0.15 ± 0.02^{a}	43.20 ± 0.74^{a}	26.41 ± 0.16^{a}
	2	1.4724 ± 0.00^{b}	0.18 ± 0.00^{b}	45.61 ± 0.25^{de}	29.83 ± 0.41^{b}
	4	1.4730 ± 0.00^{c}	0.20 ± 0.00^{c}	44.69 ± 0.05^{bc}	30.27 ± 0.33^{bc}
	8	1.4732 ± 0.00^{d}	0.22 ± 0.00^{c}	44.13 ± 0.05^{b}	30.99 ± 0.44^{d}
	12	1.4733 ± 0.00^{d}	0.24 ± 0.00^{d}	45.19 ± 0.03^{cd}	31.29 ± 0.48^{d}
	16	1.4733 ± 0.00^{d}	0.29 ± 0.00^{e}	46.25 ± 0.05^{e}	32.87 ± 0.26^{e}
	20	1.4734 ± 0.00^{e}	0.42 ± 0.00^{f}	50.99 ± 0.31^{f}	34.11 ± 0.10^{f}

Each value in the table represents the mean of three replicates ± SD.
Values at low or medium power setting within a column with the same superscript letters are not significantly different at P>0.05.

Refractive indices (RI) of the oil samples were increased with increasing heating time (Table 2). RI increased slowly at the low-power setting and more rapidly at the medium-power setting and the amount of RI increment at low- power setting (0.0003 unit from initial) was lower than that at medium-power setting (0.0014 unit from initial). The changes in percentage of free fatty acid (FFA) of samples during microwave heating are depicted in Table 2. No statistically changes (P>0.05) in FFA were observed after 2 min of heating at low-power setting. The FFA of the oil samples increased significantly (P<0.05) with longer heating time, particularly those heated at medium-power setting. Although the FFA content is an index of hydrolytic rancidity, it was nevertheless measured, as free acids contribute to the development of off-flavours and off-odours in the oil (Tan *et al*., 2002). The present results showed that the FFA contents increased due to production of fatty acids for the hydrolysis of triglyceride molecules as affected by microwave energy. Table 2 shows the effect of microwave heating on changes in viscosity measured at 30 and 40°C for corn oils at two different microwave power settings. There was a small increases in the values as a consequence of the microwave heating at lower-power setting, a more pronounced increase observed at medium-power setting. The amounts of increment in viscosity from the initial at low-power setting (2.53 units at 30°C and 4.63 units at 40°C) were lower than those measured at medium-power setting (7.79 units at 30°C and 7.70 units at 40°C). Significant effect on measuring temperature was found and the values at 30°C for all microwave setting times and powers were higher than those measured at 40°C.

Changes in peroxide value (PV) during microwave heating are presented in Table 3. The PV of the sample increased as microwave heating at the medium-power setting progressed till it reached the peak value (7.85) and then gradually decreased, whereas at low-power setting, this value increased gradually up to 20 min of heating. Similar observation was noticed for corn and soybean oils by Tan *et al.* (2001) during microwave heating. The formation of hydroperoxides was more pronounced at the medium-power setting than at the low-power setting. These results also indicate the rapid decomposition of hydroperoxides to secondary oxidation products at elevated temperature. These compounds are extremely unstable and decompose via fission, dehydration, and formation of free radicals to yield a variety of chemical products, such as alcohols, aldehydes, ketones, acids, dimers, trimers, polymers, and cyclic compounds (Tan *et al*., 2001). As compared to PV, the p-Anisidine value (p-AV) is a more meaningful test because it measures the accumulation of secondary oxidation products. As shown in Table 3, the oil p-AV increased slowly at the low-power setting and more rapidly in the medium-power setting at each treatment time, as consequence of a higher rate of secondary lipid oxidation product formation. The present results also revealed the value of p-AV of the sample during microwave heating

Table 3. Peroxide value, p-Anisidine value, TOTOX value and total polar compound of corn oil during microwave heating

Power setting	Heating time (min)	Peroxide value (meq/kg oil)	*p*-Anisidine value	TOTOX value	Total polar compound (%)
Low	0	4.34 ± 0.40^{a}	1.22 ± 0.04^{a}	9.90 ± 0.10^{a}	5.25 ± 0.26^{a}
	2	4.78 ± 0.04^{a}	2.32 ± 0.12^{b}	11.88 ± 0.13^{b}	8.51 ± 2.19^{b}
	4	4.85 ± 0.05^{a}	2.43 ± 0.32^{b}	12.13 ± 0.23^{b}	8.59 ± 0.26^{b}
	8	5.71 ± 0.32^{b}	2.42 ± 0.16^{b}	13.84 ± 0.71^{c}	11.16 ± 2.17^{bc}
	12	5.79 ± 0.08^{b}	2.63 ± 0.30^{bc}	14.21 ± 0.21^{d}	11.21 ± 0.69^{bc}
	16	6.87 ± 0.31^{c}	2.74 ± 0.27^{bc}	16.48 ± 0.83^{e}	11.33 ± 1.68^{bc}
	20	6.95 ± 0.06^{c}	3.06 ± 0.31^{c}	16.96 ± 0.19^{e}	12.10 ± 0.27^{c}
Medium	0	4.34 ± 0.40^{a}	1.22 ± 0.04^{a}	9.90 ± 0.10^{a}	5.25 ± 0.26^{a}
	2	6.48 ± 0.04^{c}	2.91 ± 0.16^{b}	15.87 ± 0.23^{b}	14.28 ± 2.31^{b}
	4	7.62 ± 0.12^{d}	3.12 ± 0.25^{c}	18.36 ± 0.21^{c}	15.36 ± 1.57^{c}
	8	7.85 ± 0.07^{d}	7.29 ± 0.21^{d}	22.99 ± 0.25^{d}	15.83 ± 1.67^{c}
	12	6.03 ± 0.06^{b}	17.44 ± 0.44^{e}	29.50 ± 0.54^{e}	17.43 ± 0.46^{d}
	16	6.67 ± 0.35^{c}	24.01 ± 0.26^{f}	37.35 ± 0.96^{f}	20.43 ± 1.61^{e}
	20	6.45 ± 0.21^{c}	26.07 ± 0.42^{g}	38.97 ± 0.43^{g}	25.65 ± 2.19^{f}

Each value in the table represents the mean of three replicates ± SD.
Values at low or medium power setting within a column with the same superscript letters are not significantly different at $P>0.05$.

at medium-power setting increased significantly ($P<0.05$) with times. The amounts of increment in p-AVs from the initial were 1.84 and 24.85 units for heating at low-power setting and medium-power setting, respectively. Total oxidation (TOTOX) value measures both hydro-peroxides and their breakdown products, and provides a better estimation of the progressive oxidative deterioration of fats and oils. As shown in Table 3, The TOTOX value in the oil samples increased with the time increment and the rates of increments were significantly different ($P<0.05$) from each other. At the end of heating period, the TOTOX value at medium-power setting (38.97) was found to be higher than that at low-power setting (16.96). The total polar compound (TPC), an indication of hydrolysis and oxidation of triglycerides and formation of free fatty acids, mono, diglycerides as well as other compounds is not only concerned with hydrolysis of triglycerides but is related to saturation and unsaturation of the media as suggested by Choe and Min (2007), therefore it has been suggested that polar compounds increase as unsaturation is increased (Oztop, 2007). As can be seen in Table 3, total polar compounds in corn oil sample increased significantly ($P<0.05$) at medium-power setting as heating progressed and reached 25.65% at the end of 20 min heating. On the other hand, the increments in TPC at low-power setting were not significant ($P>0.05$). Therefore, microwave treated sample at low-power setting had a lower concentration of polar compounds compared to the samples treated at medium-power setting which might be partially regarded as the products in lower concentration of hydro-peroxide decomposition namely aldehydes, ketones, acids, and alcohols, secondary oxidation products formed in the samples treated at low-power setting.

Tocopherols as lipophilic type of antioxidants, suffered during microwave heating a certain degree of degradation. Tocopherols were thus able to protect microwave heated oils, especially at higher tocopherol content against oxidation (Kreps *et al.*, 2014). The major biological role of vitamin E is to protect unsaturated fatty acids contained in vegetable oils from oxidation by free radicals. They are susceptible to high temperature deterioration. The stability of the vitamin E isomers varies during heating. Tocopherols composition of the fresh and heated oil samples is presented in Table 4. The γ-tocopherol (140.00 ppm) was high in fresh corn oil followed by δ (8.54 ppm) and β (4.25 ppm) isomers. The α-tocopherol was not detected in the sample. The total tocopherol level decreased from 152.79 ppm in fresh oil to 17.90 ppm in the sample heated at low-power setting, whereas no any tocopherol isomer was detected at the end of heating operated at medium-power setting. The reduction of these tocopherol isomers were evident as heating progressed. The present results proved that microwave heating caused bigger reduction of γ-tocopherol in the corn oil compared to other isomers. The β-tocopherol was disappeared after 16 min of heating at low-power setting and after 2

Table 4. Tocopherol composition of corn oil during microwave heating

Power setting	Heating time (min)	Tocopherol (ppm)				
		α	β	γ	δ	Total
Low	0	-	4.25 ± 0.15	140.00 ± 0.01	8.54 ± 0.22	152.79
	2	-	4.05 ± 0.15	143.00 ± 0.50	8.49 ± 0.03	155.54
	4	-	3.47 ± 0.67	124.00 ± 1.00	8.13 ± 0.05	135.60
	8	-	3.61 ± 0.17	120.00 ± 1.00	7.57 ± 0.11	131.18
	12	-	3.11 ± 0.00	88.10 ± 1.20	7.59 ± 0.03	98.80
	16	-	2.98 ± 0.00	83.85 ± 3.55	7.15 ± 0.06	93.98
	20	-	-	13.95 ± 0.65	3.95 ± 0.05	17.90
Medium	0	-	4.25 ± 0.15	140.00 ± 0.01	8.54 ± 0.22	152.79
	2	-	3.61 ± 0.18	104.00 ± 1.00	7.35 ± 0.10	114.96
	4	-	-	26.85 ± 0.05	5.28 ± 0.08	32.13
	8	-	-	21.60 ± 0.30	4.81 ± 0.21	26.41
	12	-	-	7.45 ± 0.00	2.49 ± 0.05	9.94
	16	-	-	-	1.17 ± 0.03	1.17
	20	-	-	-	-	-

- = Not detected

Each value in the table represents the mean of two replicates ± SD.

min of heating at medium-power setting. The lowest percentage of reduction was found in the sample treated at low-power setting.

Conclusions

In this study, microwave power from low to medium has been shown to influence the quality of oils. Most of the degradative indicators suggested that the degradation rate was the fastest in corn oils heated at medium-power setting compared to low-power setting. Although many changes occurred in the oil quality indicators during heating, the maximal values for FFA and PV remained within the acceptable limits for edible oils, showing that microwave heating does not lead to major degradation of the oil quality. The heating reduced the various vitamin E isomers in corn oil and highest reduction was detected in γ-tocopherol. The highest increased or decreased amounts in analytical values were observed for the corn oil heated at medium-power setting. Other conventional heating techniques and trials in real cooking condition could be carried out to complete the present work.

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