EFFECT OF MICROWAVE HEATING ON THE QUALITY CHARACTERISTICS OF CANOLA OIL IN PRESENCE OF PALM OLEIN

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ABSTRACT

Background. Microwave heating is one of the most attractive cooking methods for food preparation, commonly employed in households and especially in restaurants for its high speed and convenience. The chemical constituents of oils that degrade during microwave heating do so at rates that vary with heating temperature and time in a similar manner to other type of processing methods. The rate of quality characteristics of the oil depends on the fatty acid composition and the minor components during heating. Addition of oxidative-stable palm olein (PO) to heat sensitive canola oil (CO), may affect the quality characteristics of CO during microwave heating. The aim of this study was to evaluate how heat treatments by microwave oven affect the quality of CO in presence of PO.
Material and methods. The blend was prepared in the volume ratio of 40:60 (PO:CO, PC). Microwave heating test was performed for different periods (2, 4, 8, 12, 16 and 20 min) at medium power setting for the samples of CO and PC. The changes in quality characteristics of the samples during heating were determined by analytical and instrumental methods.
Results. In this study, refractive index, free fatty acid content, peroxide value, *p*-anisidine value, TOTOX value, specific extinction, viscosity, polymer content, polar compounds and food oil sensor value of the oils all increased, whereas iodine value and $C_{18:2}/C_{16:0}$ ratio decreased as microwave heating progressed. Based on the most oxidative stability criteria, PO addition led to a slower deterioration of CO at heating temperatures. The effect of microwave heating on the fatty acid composition of the samples was not remarkable. PO addition decelerated the formation of primary and secondary oxidation products in CO. However, effect of adding PO to CO on the formation of free fatty acids and polymers during microwave treatment was not significant ($P < 0.05$). No significant difference in food oil sensor value was detected between CO and PC throughout the heating periods.
Conclusion. Microwave heating caused formation of comparatively lower amounts of some degradative products in PC compared to CO indicating a lower extent of oxidative degradation of PC.

Key words: microwave heating, canola oil, fatty acids, polar compounds

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INTRODUCTION

Microwave heating is considered as an efficient and ideal method of food preparation as compared to the conventional method due to the shorter time and the lower temperature of processing. The speed and convenience of using a microwave oven are among other advantages of employing this appliance. These have brought about its widespread application for food preparation in recent decades for domestic use, as well as for industrial processes [Baffler 1993, Cerretani et al. 2009]. Heating of food in a microwave oven is caused by interaction of an electromagnetic field with the chemical constituents of food. These interaction comprising molecular friction and excitation generate heat necessary for cooking purposes [Inchingolo et al. 2013, Mishra et al. 2012, Domiszewski et al. 2011]. In vegetable oils exposed to microwave energy, the higher the amount of polyunsaturated fatty acids in the oils, the greater was the rate of quality deterioration of the oils [Yoshida et al. 1992]. Canola is one of the most important oil seed crops in the world. Research indicates that the fatty acid composition of CO is especially favourable in terms of health benefits when used as part of a nutritionally balanced diet. It contains the lowest concentration of saturated fatty acids (7%) among the vegetable oils [Ackman 1990]. The lack of frying stability and poor frying performance of CO related to high levels of linoleic and linolenic acids has been documented [Warner and Mounts 1993]. Moreover, its high cost restricts its usage on a major scale. Therefore, the use of more heat stable oils of comparatively low price would be desirable. PO is available in huge amounts at comparatively low price, while the availability of high oleic oils is limited at the moment, resulting in a higher oil price [Norhaizan et al. 2013]. However, the price is an important modulatory factor in the market, because for the production of fried food the oil is the most expensive part. PO is generally used as frying oil because it has natural antioxidants like tocopherols and β-carotene and balanced unsaturated and saturated fatty acid contents which are good for health [Khan et al. 2011]. Moreover, PO is being used increasingly in frying operations, and because of its inherent excellent frying properties, improves the frying quality of other vegetable oils when it is blended with them [Teah 1988]. Addition of oxidative-stable

PO to canola oil might affect the quality degradation of canola oil during microwave heating.

The effects of microwave treatments on the thermooxidative degradation and on some physical and chemical parameters of CO have been studied [Thais and Marisa 1998, 2001, ChiAvaro 2010]. Nothing has been reported on how microwave heating affects the quality of CO in presence of PO. In the present study, efforts have been made to investigate the effects of PO addition at 40% level on the quality changes of CO during microwave heating by a combination of the most effective analytical and instrumental methods.

MATERIAL AND METHODS

Materials

Refined canola oil (Wintercorn Edible Products, Australia) and palm olein (Sime Darby Food and Beverages, Malaysia) were collected from a local supermarket. The oil blend was formulated by blending PO with CO in the volume ratio of 40:60 (PO:CO, PC). The mixtures were stirred in a magnetic stirrer for 20 min for homogenization. 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

A domestic microwave oven (Model NN-ST65IM, Panasonic Co. Ltd., China) was used in this study for the samples of CO and PC. 90 mL of oil were divided into two 50 mL beakers, which were placed at equal distances on the turntable rotary plate of the microwave oven. The samples were exposed to microwave heating at medium power setting, for different periods (2, 4, 8, 12, 16 and 20 min). The two samples were combined after microwave treatment and before analysis. The final oil temperatures at various heating times were measured by inserting a calibrated thermocouple (Model HI 9043, Hanna Instruments Ltd., Bedfordshire, UK) into the oil immediately after removal from the oven. In order to have a standardize operation;

the microwave oven was left open after each heating test, so that the oven temperature was reduced to approximately 36°C before the next test. Finally, the samples were collected and stored at –16°C for analysis.

Standard physicochemical analyses

American Oil Chemists' Society official methods [AOCS 1987] were used for determining refractive index (method Cc 7-25), free fatty acid content (method Ca 5a-40), iodine value (method Cd 1b-87) and peroxide value (method Cd 8-53). Specific extinctions (method p2.15) at 233 and 269 nm ($E^{1\%}_{233}$ and $E^{1\%}_{269}$) and *p*-Anisidine value (method p2.4) of the samples were determined by means of a Jenway 6305 Spectrophotometer (Barloworld Scientific Ltd., UK) according to the PORIM [1995] test methods.

Viscosity measurement

Viscosity of the oils was measured by using a Brookfield LVDV–II+P viscometer (Brookfield Engineering Laboratories Inc., Middleboro, USA). 1 mL of oil was placed on the plate of the viscometer with spindle S-42; the viscosity of the sample was read in cP (centipoises) directly from the viscometer, which was maintained at 40°C.

Polymer content

Polymer content was determined according to the method described by Peled et al. [1975]. The oil sample was initially reacted with 1% sulfuric acid in methanol. The solution was then refluxed with a reflux condenser for about 2 h with stirring throughout. The methanolic miscella was thoroughly decanted off and the methanol-insolubles were washed with methanol. The insolubles were dissolved in 40 mL petroleum ether (60-80°C). The solvent was then removed using a rotary evaporator and the residue was dried in an oven at a temperature of 140°C. The dried residue was finally weighed after being cooled at room temperature.

Polar compounds

The total polar compound contents were determined by the mini column method [Dobarganes et al. 2000]. Briefly, about 1.0 g of oil was diluted in light petroleum ether/diethyl ether (90:10, v/v) and made up to 10 mL with the same solvent mixture. 5 mL of

the solution were applied to 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 removed by rotary evaporator; afterwards the flask was flushed under a stream of nitrogen for complete dryness. The completeness of fractionation was evaluated by analytical thin-layer chromatography in the elution system light petroleum ether: diethyl ether: acetic acid (70:40:1; v:v:v).

Food oil sensor

Food oil sensor values were measured by using the food oil sensor instrument (CapSens 5000, C-Cit Ag, Wädenswil, Switzerland).

Fatty acids composition

Fatty acids composition of the oils was determined as their methyl esters prepared by the PORIM [1995] test method p3.4. Fatty acid methyl esters (FAME) were quantified using an auto-system XL gas chromatograph (Perkin Elmer Incorporate, Massachusetts, USA) equipped with a fused silica capillary column (60 m × 0.25 mm i.d × 0.20 μm film thickness, Perkin Elmer, USA) and a flame ionization detector. Nitrogen was used as carrier gas with a flow rate of 20 mL/min. Initial temperature was set to 100°C, raised to 170°C at 20°C/min, then programmed to 230°C at 10°C/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.

Statistical analysis

Results were expressed as the means and standard deviation (SD). Significant differences between means of two oil samples were assessed with Student's *t* test. Significant differences between means of same sample were determined by Duncan's multiple range test using SPSS 11.5 software package. Differences were considered statistically significant at $P < 0.05$.

RESULTS AND DISCUSSION

Refractive indices (RI) of PC were increased insignificantly ($P < 0.05$) whereas those of CO increased significantly with increasing heating time (Table 1). The amount of RI increment in CO (0.0027 unit from initial) was similar to that of its blend PC (0.0026 unit from initial). These results could not be explained by the differences in fatty acids composition where CO contained higher amount of PUFA compared to its blend. But R1 values of the blend at corresponding heating times were significantly ($P < 0.05$) different

Table 1. Refractive index, FFA and iodine value of canola oil and its blend with palm olein during microwave heating

Parameters	Time, min	Canola oil (CO)	Palm olein : Canola oil (PC)
Refractive index (25°C)	0	1.4713 ±0.00[A]	1.4685 ±0.00[Aa]
	2	1.4715 ±0.00[B]	1.4688 ±0.00[ABa]
	4	1.4719 ±0.00[C]	1.4688 ±0.00[ABa]
	8	1.4721 ±0.00[D]	1.4691 ±0.00[BCa]
	12	1.4724 ±0.00[E]	1.4695 ±0.00[DEa]
	16	1.4725 ±0.00[F]	1.4699 ±0.00[Ea]
	20	1.4740 ±0.00[G]	1.4711 ±0.00[Fa]
Free fatty acid, %	0	0.10 ±0.03[A]	0.11 ±0.03[A]
	2	0.11 ±0.01[A]	0.13 ±0.02[B]
	4	0.11 ±0.01[A]	0.16 ±0.01[B]
	8	0.12 ±0.01[A]	0.16 ±0.01[BC]
	12	0.12 ±0.01[A]	0.17 ±0.01[BCD]
	16	0.15 ±0.02[AB]	0.19 ±0.01[CD]
	20	0.18 ±0.03[B]	0.20 ±0.02[D]
Iodine value	0	109.68±0.64[E]	93.82 ±0.14[Da]
	2	108.43±0.74[DE]	92.13 ±0.85[Ca]
	4	106.43 ±0.97[CD]	91.20 ±1.02[BCa]
	8	105.42 ±1.11[BC]	89.88 ±0.82[Ba]
	12	103.78 ±0.89[B]	87.46 ±0.37[Aa]
	16	101.30 ±1.59[A]	86.58 ±0.80[Aa]
	20	100.30 ±1.22[A]	86.48 ±0.87[Aa]

Each value in the table represents the mean of three replicates ±SD.
For same oil, values within a column with the same uppercase letters are not significantly different at $P < 0.05$.
[a]For the same heating time, refractive index, free fatty acid or I_2 value of PC was significantly different from that of CO (Student t-test, $P < 0.05$).

from those of CO. The changes in percentage of free fatty acid (FFA) of CO samples during microwave heating are depicted in Table 1. An unremarkable increase in FFA was observed for both heated oils. 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]. Addition of PO to CO at the level of 40% caused slightly higher increment of the FFA values in pure oil at the end of the heating process; this might be due to the higher rate of increment of FFA in PO during heating [Enríquez-Fernández et al. 2011]. A decrease in iodine value (IV) is consistent with the decreasing number of double bonds in the oil as it becomes oxidized. Thus, the reduction in IV during heating is often taken as a measure of oil deterioration [Fristch 1981]. IV for microwave heated CO samples gradually decreased with increasing times (Table 1). The reduction in IV was higher in CO (9.38) than in PC (7.34). However, exposing the oils to microwave heating decreases the IV of the oils and blending PO with CO results in slower rate of decrease in the double bond. Therefore, rate of oxidation of blend was lower compared to pure CO.

The peroxide value (PV) was taken as a measure for the degree of oxidation during the microwave heating of oil samples. PV values did not increase gradually but showed significant alterations during microwave heating (Table 2). It can be seen that, the rate of peroxide formation in PC was lower than that in CO during microwave heating. Oil samples exhibited maximum PV values at 8 min of heating for CO (7.95) and at 12 min for PC (7.15). The PVs of these oils increased as microwave heating progressed till they reached the highest values. Similar observations were followed for various vegetable oils by Clark and Serbia [1991] and Tan et al. [2002] during microwave heating. This is a clear indication of the rapid decomposition of hydroperoxides into secondary oxidation products at high temperatures. In the present study, addition of PO decreased the increment of peroxide value of substrate oil, might be attributed to decreasing amount of linoleic and linolenic acids present in the blend. 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 2, the p-AVs of CO increased more

rapidly than its blend, mainly because of its highly unsaturated nature. At the end of the treatment, the amounts of increment in p-AVs from the initial were 15.16 and 13.10 units for heating media CO and PC, respectively. CO exhibited the higher p-AV at each treatment time, as a consequence of a higher rate of secondary lipid oxidation product formation. However, PO addition to CO decelerated the formation of secondary oxidation products in CO. 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. It is expressed as TOTOX = 2PV+ p-AV. As shown in Table 2, The TOTOX value in the oil samples CO and PC 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 of CO (28.08) was found to be higher than that of PC (24.87). Addition of PO resulted in a marked decline in TOTOX values of CO, thus showing enhancement of the oxidative state of this substrate oil.

The absorbances at 232 ($E^{1\%}_{233}$) and 270 nm ($E^{1\%}_{269}$), due to the formation of conjugated dienes and trienes that are produced for the oxidation of polyunsaturated fatty acids, are good index for measuring the degradation of microwave heated samples. Changes in ultraviolet absorptivity of CO and PC at 232 and 270 nm are shown in Table 3. The variations of $E^{1\%}_{233}$ and $E^{1\%}_{269}$ exhibited a regular increase with heating duration at medium power setting. The $E^{1\%}$ values in the samples CO and PC showed significant ($P < 0.05$) difference throughout the heating period. After 20 min of heating, the final $E^{1\%}$ values at 233 nm and 269 nm were: 2.28 and 1.24 in CO and 2.03 and 1.01 in PC, respectively. The conjugated dienes were formed at higher levels than the conjugated trienes which corresponded with results published by Dostálová et al. [2005]. However, PO addition to the pure oil decelerated conjugated dienes and trienes formation in CO during microwave heating times. Since microwave heating time is associated with absorptivity in the UV spectrum, this analysis may be employed to compare the oxidative stability of oils under microwave heating. The change in viscosity indicates significant structural changes. This has been attributed to polymerization and the formation of high- molecular-weight

Table 2. Peroxide, *p*-Anisidine and TOTOX values of canola oil and its blend with palm olein during microwave heating

Parameters	Time, min	Canola oil (CO)	Palm olein : Canola oil (PC)
Peroxide value meq/kg of oil	0	1.16 ±0.01[A]	1.17 ±0.02[Aa]
	2	3.36 ±0.31[B]	3.31 ±0.11[Ba]
	4	5.62 ±0.44[CD]	5.18 ±0.08[C]
	8	7.95 ±0.11[E]	5.94 ±0.51[Da]
	12	6.68 ±0.72[D]	7.15 ±0.08[Da]
	16	6.60 ±0.40[D]	6.31 ±0.21[D]
	20	5.25 ±0.95[C]	4.91 ±0.14[C]
p-Anisidine value	0	2.43 ±0.04[A]	2.40 ±0.19[A]
	2	5.54 ±0.38[B]	4.13 ±0.14[Ba]
	4	6.47 ±0.12[C]	5.00 ±0.12[Ca]
	8	7.43 ±0.06[D]	7.10 ±0.12[Da]
	12	10.24 ±0.09[E]	9.11 ±0.15[Ea]
	16	13.51 ±0.13[F]	12.04 ±0.20[Fa]
	20	17.59 ±0.06[G]	15. 50 ±0.04[Ga]
TOTOX value	0	4.75 ±0.08[A]	4.74 ±0.12[Aa]
	2	12.26 ±0.32[B]	10.75 ±0.26[Ba]
	4	17.71 ±0.19[C]	15.36 ±0.10[Ca]
	8	23.32 ±0.28[D]	18.65 ±0.22[Da]
	12	23.60 ±0.09[D]	23.40 ±0.10[Ea]
	16	26.71 ±0.70[E]	25.58 ±0.54[G]
	20	28.08 ±0.44[F]	24.87 ±0.25[Fa]

Each value in the table represents the mean of three replicates ±SD.
For same oil, values within a column with the same uppercase letters are not significantly different at $P < 0.05$.
[a]For the same heating time, peroxide value, *p*-Anisidine value or TOTOX value of PC was significantly different from that of CO (Student t-test, $P < 0.05$).

compounds *via* carbon-to-carbon and/or carbon-to-oxygen-to-carbon bridges between fatty acids [Maskan 2003]. Table 3 shows the effect of microwave heating on the changes in viscosities for CO samples at medium power setting. The viscosity of microwave heated oils increased significantly ($P < 0.05$) with times. The amount of increment in CO from the initial was 17.90

units; being higher than 12.30 units detected in PC. Similar viscosity trends were observed with various heated vegetable oils by Albi et al. [1997].

Polymer contents (POC) of microwave heated oils CO and PC were increased insignificantly ($P < 0.05$) with heating times (Table 4). This parameter related to formation of higher molecular weight substances by

Table 3. Specific extinction and viscosity of canola oil and its blend with palm olein during microwave heating

Parameters	Time, min	Canola oil (CO)	Palm olein : Canola oil (PC)
$E^{1\%}_{1cm}$ at 233 nm	0	1.36 ±0.05[A]	1.25 ±0.05[Aa]
	2	1.54 ±0.05[B]	1.40 ±0.03[ABa]
	4	1.60 ±0.03[B]	1.45 ±0.02[Ba]
	8	1.74 ±0.03[C]	1.53 ±0.05[Ca]
	12	1.81 ±0.04[C]	1.66 ±0.04[Da]
	16	1.90 ±0.03[D]	1.70 ±0.02[Ea]
	20	2.28 ±0.02[E]	2.03 ±0.09[Fa]
$E^{1\%}_{1cm}$ at 269 nm	0	0.70 ±0.02[A]	0.61 ±0.02[Aa]
	2	0.78 ±0.02[A]	0.66 ±0.01[Ba]
	4	0.83 ±0.04[AB]	0.72 ±0.02[Ca]
	8	0.88 ±0.03[B]	0.75 ±0.03[Da]
	12	0.96 ±0.02[C]	0.83 ±0.02[Da]
	16	1.07 ±0.04[D]	0.92 ±0.02[Ea]
	20	1.24 ±0.05[E]	1.01 ±0.02[Fa]
Viscosity, cP	0	32.43 ±0.12[A]	35.20 ±0.16[Aa]
	2	35.20 ±0.16[B]	37.37 ±0.12[Ba]
	4	38.53 ±0.17[C]	38.83 ±0.17[C]
	8	43.10 ±0.29[D]	42.50 ±0.08[D]
	12	45.20 ±0.16[E]	43.10 ±0.08[Ea]
	16	47.93 ±0.19[F]	44.40 ±0.08[Fa]
	20	50.33 ±0.24[G]	47.50 ±0.08[Ga]

Each value in the table represents the mean of three replicates ± SD.
For same oil, values within a column with the same uppercase letters are not significantly different at $P < 0.05$.
[a]For the same heating time, specific extinction or viscosity of PC was significantly different from that of CO (Student t-test, $P < 0.05$).

polymerization, was found to be slightly higher in CO than in PC. So addition of PO slowed down slightly the rate of polymerization in CO. The total polar compound (TPC) content, 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 et al. 2007]. As can be seen in Table 4, total polar compounds in CO samples increased significantly ($P < 0.05$) as heating progressed and reached 16.20 and 14.81% for CO and

Table 4. Polymer content, total polar compound and FOS value of canola oil and its blend with palm olein during microwave heating

Parameters	Time, min	Canola oil (CO)	Palm olein : Canola oil (PC)
Polymer content %	0	0.58 ±0.02[A]	0.57 ±0.03[A]
	2	0.83 ±0.06[B]	0.72 ±0.04[B]
	4	0.93 ±0.06[B]	0.87 ±0.06[B]
	8	1.05 ±0.07[C]	0.97 ±0.02[B]
	12	1.09 ±0.05[C]	1.04 ±0.04[C]
	16	1.24 ±0.05[D]	1.16 ±0.08[D]
	20	1.31 ±0.05[D]	1.24 ±0.04[D]
Total polar compound, %	0	4.65 ±0.19[Aa]	5.13 ±0.08[Ab]
	2	6.04 ±0.78[B]	6.17 ±0.13[B]
	4	8.09 ±0.12[C]	7.81 ±0.19[C]
	8	9.67 ±0.23[D]	8.80 ±0.17[Da]
	12	11.21 ±0.25[E]	10.07 ±0.05[Ea]
	16	14.13 ±0.18[F]	12.39 ±0.12[Fa]
	20	16.20 ±0.17[G]	14.81 ±0.18[Ga]
FOS value	0	1.08 ±0.07[A]	1.06 ±0.00[A]
	2	1.30 ±0.05[A]	1.24 ±0.04[B]
	4	1.32 ±0.05[A]	1.26 ±0.01[C]
	8	1.33 ±0.05[B]	1.29 ±0.05[D]
	12	1.35 ±0.04[C]	1.32 ±0.02[E]
	16	1.38 ±0.04[C]	1.35 ±0.02[F]
	20	1.43 ±0.02[D]	1.39 ±0.04[G]

Each value in the table represents the mean of three replicates ±SD.
For same oil, values within a column with the same uppercase letters are not significantly different at $P < 0.05$.
[a]For the same heating time, polymer content, total polar compound or FOS value of PC was significantly different from that of CO (Student t-test, $P < 0.05$).

PC, respectively at the end of 20 min heating. Therefore, microwave treated PC had a lower concentration of polar compounds compared to pure oil 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 PC. As the number of polar molecules increases, the food oil sensor (FOS) value of the oil increases. The FOS values increased over 20 min of the heating operation (Table 4). Final FOS values were attained as follows: CO (1.43) and PC (1.39). In this case, the highest TPC content and FOS value were both detected in CO. Though, the FOS values of substrate oil reduced as the result of adding PO

to CO during the microwave heating, the effect of PO addition at the level of 40% on the FOS values was not statistically significant ($P < 0.05$).

The fatty acids composition of the samples examined in this study are summarized in Table 5. The fresh CO was characterised with high level of oleic acid (62.36%) followed by linoleic (20.02%) and then linolenic (9.45%) acids. Fresh CO and its blend contained *trans* $C_{18:2}$ (0.10 to 0.15%) while no *trans* $C_{18:1}$ was detected in any sample used in this study. In this study, the effect of microwave heating on the fatty acids composition of the samples was not significant. Similar result was observed by Domiszewski et al. [2011] during microwave heating of striped catfish fillets. Both linoleic acid and palmitic acid are considered as good indicators of the extent of fat deterioration because linoleic acid is more susceptible to oxidation, whereas palmitic acid is more stable toward oxidation. Therefore, the ratio of C18:2/C16:0 may also be used to indicate the degree of oxidative deterioration

oils [Normand et al. 2001]. Upon heating, the ratio decreased slightly in all the samples. Similar patterns were observed by Tan and Che Man [1999]. The results showed that oxidation process progressed more rapidly in the pure oil as compared to the blend. The blending PO with CO led to decline the reduction in the ratio of $C_{18:2}/C_{16:0}$. The starting value of the $C_{18:2}/C_{16:0}$ ratio was low in the blend than in CO due to addition of highly saturated PO. It has been shown that heating the oil causes a fast decrease in more unsaturated fatty acids than less unsaturated or saturated fatty acids [Warner and Mounts 1993]. A highest decrease amount from the initial was observed in the PC (0.33 unit) as the high amount of linoleic acid (24.43%) detected in fresh PC, being higher than fresh CO (20.02%); this might be an experimental error in the data of fresh PC. Considering the values from 2 min of heating time, the slightly higher decrease amount was detected in the CO.

Table 5. Fatty acids composition (%) of canola oil and its blend with palm olein during microwave heating

Sample	Time min	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	*trans*-$C_{18:2}$	$C_{18:3}$	$C_{20:0}$	$C_{20:1}$	$C_{24:0}$	SFA	MUFA	PUFA	C18:2/ C16:0
CO	0	0.03	0.05	4.62	0.15	1.91	62.36	20.02	0.11	9.45	0.48	0.72	0.12	7.21	63.23	29.47	4.36
	2	0.04	0.06	4.64	0.18	1.91	62.27	19.96	0.11	9.48	0.48	0.74	0.15	7.28	63.19	29.44	4.33
	4	0.03	0.05	4.67	0.16	1.90	62.29	20.05	0.12	9.50	0.48	0.74	0.09	7.22	63.19	29.55	4.32
	8	0.04	0.06	4.66	0.17	1.88	62.40	19.93	0.10	9.42	0.48	0.72	0.16	7.28	63.29	29.35	4.30
	12	0.03	0.06	4.65	0.15	1.90	62.49	19.86	0.11	9.41	0.48	0.72	0.16	7.28	63.36	29.27	4.29
	16	0.04	0.06	4.68	0.17	1.90	62.36	19.92	0.10	9.41	0.48	0.72	0.15	7.31	63.25	29.33	4.28
	20	0.03	0.06	4.69	0.15	1.92	62.37	19.93	0.11	9.41	0.49	0.73	0.14	7.33	63.25	29.34	4.27
PC	0	0.13	0.50	20.15	20.15	2.87	48.12	24.43	ND	2.98	0.33	0.22	0.14	24.12	68.49	27.41	1.21
	2	0.10	0.40	17.45	0.15	2.59	55.82	16.73	0.10	5.72	0.41	0.44	0.10	21.05	56.41	22.45	0.96
	4	0.11	0.42	17.79	0.15	2.60	55.51	16.71	0.10	5.70	0.4	0.44	0.10	21.42	56.10	22.41	0.94
	8	0.10	0.42	18.06	0.15	2.65	55.77	16.42	0.10	5.42	0.41	0.42	0.10	21.74	56.34	21.84	0.91
	12	0.11	0.44	18.59	0.15	2.49	54.93	16.78	0.15	5.39	0.37	0.41	0.06	22.06	55.49	22.17	0.91
	16	0.10	0.42	18.41	0.15	2.67	55.47	16.37	0.11	5.40	0.41	0.42	0.10	22.11	56.04	21.77	0.90
	20	0.12	0.47	18.93	0.16	2.58	54.81	16.65	ND	5.35	0.39	0.41	0.12	22.61	55.38	22.00	0.88

ND – not detected.

CONCLUSIONS

In this study, most of the quality indicators suggested that the degradation rate was the fastest in CO compared to PC. No significant differences in the levels of some indices such as FFA, polymer content and FOS were found between the samples CO and PC showing that microwave heating does not lead to major degradation of the oil quality. The oil sample CO containing a higher percentage of PUFA shows slightly greater tendency to form primary and secondary oxidative products and also polymeric compounds during heating. It can be concluded that addition of PO to CO at 40% (v/v) slowed down the oxidative degradation rate of the CO. Other conventional heating techniques and trials in real cooking conditions could be carried out to complete the present work.

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