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The Effect of Microwave Roasting Over the Thermooxidative Degradation of Perah Seed Oil During Heating

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Abstract: The impact of microwave roasting on the thermooxidative degradation of perah seed oil (PSO) was evaluated during heating at a frying temperature (170℃). The roasting resulted significantly lower increment of the values of oxidative indices such as free acidity, peroxide value, *p*-anisidine, total oxidation (TOTOX), specific extinctions and thiobarbituric acid in oils during heating. The colour L* (lightness) value dropped gradually as the heating time increased up to 12 h, whereas a*(redness) and b* (yellowness) tended to increase. The viscosity and total polar compound in roasted PSO was lower as compared to that in unroasted one at each heating times. The tocol retention was also high in roasted samples throughout the heating period. The relative contents of polyunsaturated fatty acids (PUFAs) were decreased to 94.42% and saturated fatty acids (SFAs) were increased to 110.20% in unroasted sample, after 12 h of heating. On the other hand, in 3 min roasted samples, the relative contents of PUFAs were decreased to 98.08% and of SFAs were increased to 103.41% after 12 h of heating. Outcome from analyses showed that microwave roasting reduced the oxidative deteriorations of PSO during heating.

Key words: microwave roasting, perah seed, thermooxidative degradation, fatty acids, polar compounds

1 Introduction

In developing and under-developed countries, there is an urgent need for additional or new plant edible oils to meet the nutritional requirements of ever-increasing populations. The *Elateriospermum tapos* popularly known as perah, is a monoecious tropical canopy species which can be found in Southeast Asian (Peninsular Thailand, Peninsular Malaysia, Sumatra, Java as well as Borneo) tropical rain forest. Perah seed oil contains significant amount of α̇-linolenic acid, the essential polyunsaturated fatty acids[1]. Yong and Salimon[1] stated that perah seed oil has the potential to be developed either for food, pharmaceutical and oleochemical industries. In addition, perah seed has good nutritional values that suitable to be a new source of high protein[2]. It is mainly consumed only after being cooked (boiled or roasted)[1]. The effects of various processing methods used to prepare oilseeds for human consumption are of utmost importance. Roasting is an important pretreatment for oily seeds prior to oil extraction. It causes some desirable and/or undesirable changes in physical, chemical and nutritional properties of the seeds and extracted oils[3]. However, microwave processing of foods is a recent development, which is gaining momentum in household as well as large scale food applications[4]. This equipment 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[5]. Roasting increases the oxidative and tocopherol stability, and level of saturated fatty acids in oils[6−8].

Oxidative stability is an important indicator to determine oil quality and shelf life; because low-molecular-weight off-flavour compounds are produced during oxidation, which can make oil unacceptable to consumers or for industrial use as a food ingredient[9]. During heating of oil, a number of physical and chemical changes involving a complex

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pattern of thermolytic and oxidative reactions with the formation of some decomposition products occur in fats and oils[10, 11]. Monitoring the changes in properties of oils during heating is an effective method to assess thermal oxidation in the oils. Effects of roasting of pumpkin seed[6], mustard seed[10] and sesame seeds[12] on the oxidative stability of oils during thermal oxidation were investigated. Some investigations have been carried out in recent years regarding the chemical characteristics of perah seed or seed oil[1, 2, 13], but no information, at least to the best of our knowledge, was available in the scientific databases for microwave roasted PSO under extreme thermal conditions. Such information is needed to understand its stability under adverse thermal conditions, and to observe its degradation pattern. Therefore, the current objective was to study the influence of microwave roasting on oxidative degradation of PSO at elevated temperature (170℃).

2 Materials and Methods

2.1 Materials

Freshly harvested and dried perah seeds (3 kg, *Elateriospermum tapos* Blume) were purchased from local market at Benta, Kuala Lipis, Pahang, in August 2014. The mature, healthy seeds were sorted and stored at 4℃ in sealed plastic bags. The various chemicals and reagents used were of analytical grade. *p*-Anisidine and silica gel (grade 60, 70-230 mesh) were products of Merck (Darmstadt, Germany). Standards of fatty acid methyl esters were procured from Supelco Chemical Co. (Bellefonte, PA, USA). All other chemicals and solvents were from J.T. Baker (Phillipsburg, USA) or Quality Reagent Chemical Co. Ltd. (New Zealand) unless otherwise stated.

2.2 Roasting and extraction protocol

A domestic size microwave oven (Model NN-ST65IM, Panasonic Co. Ltd., China) at 2450 MHz with power output of 900 W was used. The perah seeds were placed in single layer in a Pyrex petri dish (12- cm diameter) and roasted at medium power setting, for different periods (1, 2, and 3 min) after covering the dish based on trial results. The roasting treatment was carefully optimized in such a way that it resulted in optimum roasting without burning. The final seed temperatures at various roasting times were measured by inserting a calibrated thermocouple (Model HI 9043, Hanna Instruments Ltd., Bedfordshire, UK) into the seeds immediately after removal from the oven. After roasting, the seeds were allowed to cool to ambient temperature. The seed coats were manually removed from raw or roasted seeds and the seeds were reduced to fine powder. The Soxhlet method (no. 963.15) as described by AOAC[14] was used to extract oil with n-hexane for 8 h. After extraction, the oil in hexane mixture was filtered followed by evaporation of the solvent *in vacuo* at 45℃. The resulting oil was weighed and stored into capped glass bottles at a temperature below −16℃ for further analysis.

2.3 Thermal oxidation of samples

The roasted or unroasted seed oil samples (80 g) were weighed into 100 mL glass beakers and placed in an electric oven at 170℃, in order to accelerate the lipid oxidation and thermal degradation. Oil samples were withdrawn at intervals of 0, 4, 8, and 12 h and flushed with nitrogen, covered with parafilm and kept at −16℃ for further analysis.

2.4 Oxidative indices

American Oil Chemists' Society official methods[15] were employed for determining free acidity (method Ca 5a-40), peroxide value (method Cd 8-53) and thiobarbituric acid value (method Cd 19-90). 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 measured by means of a Jenway 6305 Spectrophotometer (Barloworld Scientific Ltd., UK) following PORIM[16] test methods. Total oxidation or TOTOX value was calculated as: TOTOX = 2PV + *p*-AV[17].

2.5 Color and viscosity

The color values of the oils (L*, a* and b*) were measured with a Minolta chroma meter CR-10 (Minolta, Osaka, Japan). The viscosity of the oil sample was determined by a Brookfeld DV II+, viscometer (Brookfield Engineering Laboratories Inc., Middleboro, USA) with a S-42 spindle at 40℃.

2.6 Total polar compounds (TPC)

The TPC contents were determined by the mini column method[18]. Briefly, 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. Five milliliters 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).

2.7 Tocol analysis

Tocopherol and tocotrienol composition of the samples were determined using HPLC (Agilent 1100 series, Agilent Technologies, Wilmington, USA) according to the AOCS[15] 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. Tocols were determined by comparing their retention times with those of standard ones.

2.8 Fatty acid composition (FAC)

The FAC of the oils was determined as their methyl esters prepared by the PORIM[16] test method p3.4. Fatty acid methyl esters (FAME) were quantified using an autosystem 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℃, raised to 170℃ at 20℃/min, then programmed to 230℃ at 10℃/min, and finally heated to 250℃ at 30℃/min. The detector and injector temperatures were both maintained at 250℃. Methyl esters were quantified by comparing the retention times and peak area of the unknowns with known FAME standard mixtures.

2.9 Statistical analysis

All data were expressed as the mean and standard deviation (SD) and were subjected to one way analysis of variance (ANOVA). Mean values were compared at $p < 0.05$ significant level by Duncan's multiple range test using IBM SPSS 22 statistics.

3 Results and Discussion

3.1 Extraction yield and changes in oxidative indices

The crude oil levels in perah seed were in the range of 33.71% (DM) for unroasted sample to 35.62% (DM) for 3 min roasted one. The yield of crude oil increased with increasing roasting times. Hojjati *et al.*[19] also reported that microwave roasting increased the oil content in almonds.

Free acidity is an analytical parameter frequently used to evaluate the hydrolysis extension in vegetable oils during thermal process. An increase in this parameter indicates a higher presence of free fatty acids in the vegetable oil, a direct consequence of hydrolysis, being an important indicator of oil chemical deterioration[20]. With the increasing heating exposition times, the accumulation of free fatty acids was increased in all samples and at the end of 12 h heating, the percentages of free acidity in unroasted sample was significantly ($p < 0.05$) higher (7.83) compared to roasted ones (6.73-7.53) (Fig. 1a). During heating, the accumulation of primary oxidation products as measured by peroxide value (PV) was faster in unroasted sample compared to the roasted samples (Fig. 1b). However, oils from roasted seeds had the lowest ($p < 0.05$) PV compared to unroasted ones at all corresponding heating times, indicating a lower extent of hydroperoxides in roasted ones. The *p*-Anisidine value (*p*-AV) reflects the accumulation of secondary oxidation products. At the beginning of oxidation test, oils from the roasted samples had higher (2.83-3.77) *p*-AV while the unroasted sample had relatively low (2.41) level (Fig. 1c). The *p*-AVs, from lowest to highest, were displayed in samples roasted 0, 1, 2, and 3 min after 12 h thermal treatment. Previous reports on apricot kernel oil[21] or pumpkin seed oil[6] also confirmed that roasted seed oils contained lower primary and secondary oxidation products as compared to the oils from unroasted seeds during oxidation test. Figure 1d shows that TOTOX values in roasted and unroasted seed oil samples increased with prolonged oxidation time. Significant differences ($p < 0.05$) in TOTOX values in perah samples were noticed after 12 h of oxidation test. At the end of 12 h heating, TOTOX value was found to be highest ($p < 0.05$) in unroasted sample (46.56) with the lowest obtained in 3 min roasted sample (39.84). In the present study, the levels of TOTOX values were not increased steadily with increasing heating time; there was an initial sharp increase for all the samples up to 4 h, after which the rate slowed down.

As shown in Fig. 2a, the formation of secondary lipid peroxidation products as examined by thiobarbituric acid (TBA) values showed significant increasing trends during the thermal treatment for all samples. At the end of 12 h heating, unroasted sample exhibited the highest TBA (0.38), while 3 min roasted sample exhibited the least (0.24). The increasing trend in oxidation of unroasted oil samples, as illustrated in TBA values, compared with roasted ones, was similar to that obtained for oxidation products as reflected in PV and *p*-AV values. Changes in the ultraviolet absorption at 233 and 269 nm ($E^{1\%}_{233}$ and $E^{1\%}_{269}$) are associated with the changes in the conjugated dienes and trienes that are produced due to the oxidation of PUFAs[22]. The $E^{1\%}$ at 233 and 269 nm for all the samples increased significantly ($p < 0.05$) throughout the heating periods (Figs. 2b and 2c). The levels of conjugated dienes and trienes at the end of heating were however lowest in 3 min roasted samples followed by 1 and 2 min roasted samples, with highest levels found in unroasted samples. The better oxidative stability of PSO prepared from roasted seed was possibly due to the formation of Maillard reaction products (MRPs) during the roasting process which are known to positively influence products' shelf life[23]. Various mechanisms involved in the antioxidant activity of MRPs include radical chain-breaking activity[24], scavenging of reactive oxygen species, decomposing hydroperoxides

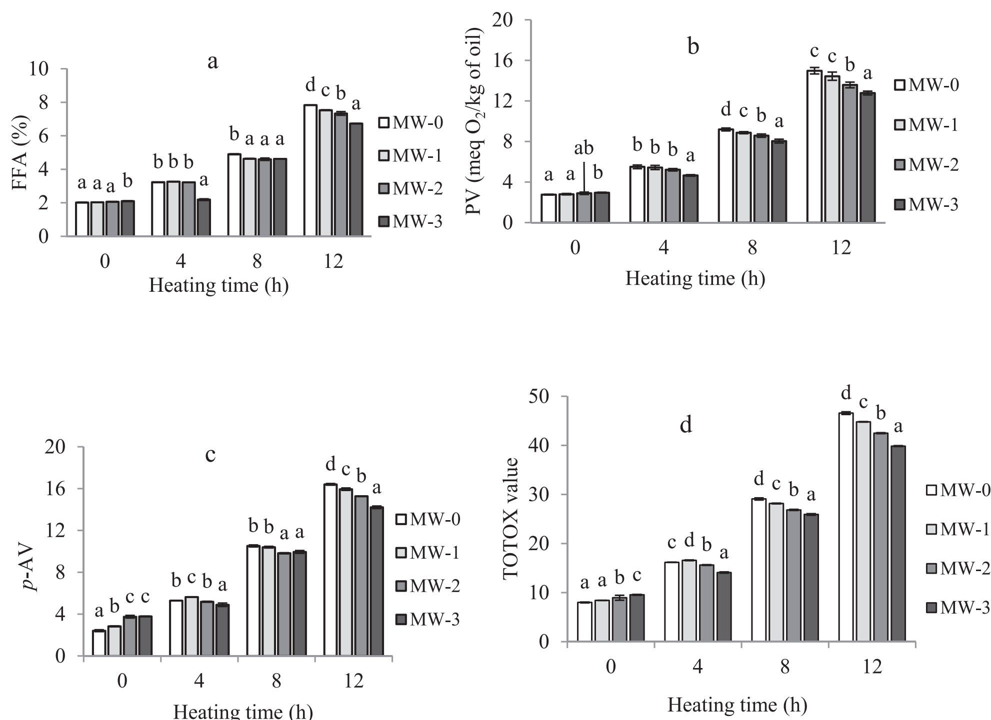

Fig. 1 Changes of chemical characteristics of unroasted (MW-0) and roasted (MW-1, roasted at 1 min; MW-2, roasted at 2 min and MW- 3, roasted at 3 min) PSOs during heating at 170℃. (a) FFA, (b) peroxide value, (c) *p*- Anisidine value, and (d) TOTOX value. Each value is the mean ± standard deviation of triplicate determinations. Values in each heating grouping with different letters on bar, are significantly different ($p<0.05$).

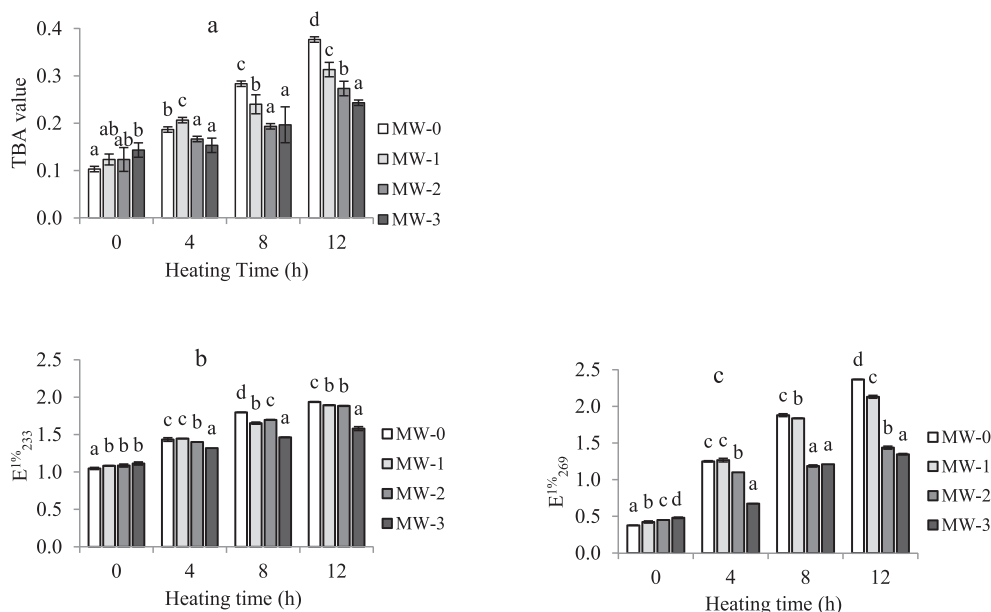

Fig. 2 Changes of TBA value (a) and specific extinctions at 232 (b) and 269 nm (c) of unroasted (MW-0) and roasted (MW-1, roasted at 1 min; MW-2, roasted at 2 min and MW- 3, roasted at 3 min) PSOs during heating at 170℃. Each value is the mean ± standard deviation of triplicate determinations. Values in each heating grouping with different letters on bar, are significantly different ($p<0.05$).

and metal chelation, thus retarding the formation of primary and secondary oxidation products[25]; thereby extending the shelf life of oils.

3.2 Changes in color and viscosity

The Change in oil colour is the combined result of oxidation, polymerisation and other chemical changes[26]. Changes in the colour parameters (L*, a*, and b* values) of roasted or unroasted perah seed oils as a function of heating times, are shown in Table 1. As the heating time increased, the L* value of the oils tended to decrease, the oils were getting darker. The darker colour indicates a high content of free fatty acids and polar compounds in oil[27]. The values for *a** and *b** were increased with increasing heating times. That is, the higher the heating times, the deeper the red and yellow colours in the oils. The present results are in accordance with the results for palm olein[28] and for tomato seed oil[29] during heating at 180℃. At the end of 12 h heating, the L*, a* and b* values were reached to 50.39, −1.33, and 10.13 respectively for unroasted samples, and to 47.43, −0.90, and 11.50 respectively for 3 min roasted samples. The changes (increase/decrease) in colour values for unroasted samples were however higher compared to roasted ones indicating the impact of roasting process of perah seeds during thermal oxidation of oil. This confirms the results of other oxidative parameters as discussed earlier that showed the unroasted sample to be more susceptible to oxidation at high temperature than the samples exposed to microwave.

Increase in viscosity was caused due to the formation of high molecular weight polymers[30]. The large polymer molecules with a molecular weight range of 692 to 1600 Daltons, are formed by a combination of -C-C-, -C-O-C-, and -C-O-O-C- bonds[31]. These are either acyclic or cyclic depending on the oil types, heating temperature, reaction process and kinds of fatty acids consisting of the oil[31]. The more viscous the heated oil, the higher the degree of deterioration[22]. As shown in Table 1, viscosity increased from initial values of 32.90, 33.10, 33.80, and 34.60 to 40.53, 39.75, 39.34, and 38.89 cP for the samples roasted for 0, 1, 2, and 3 min, respectively, after 12 h thermal treatment. These results clearly revealed the higher deteriorative effect of oxidation and polymerization in unroasted samples compared to roasted ones. Roasting the seeds resulted in the lower increases of the viscosity in oils during heating. Increase in viscosity of sunflower oil with frying time has been reported previously[30].

3.3 Changes in total polar compounds and tocols

Formation of polar compounds, which indicates oil deterioration, is strongly related with the primary and secondary oxidation that takes place during heating[32]. The amount of total polar compound (TPC) in all the oil samples increased with the heating time increment and the rates of increments were significantly different ($p<0.05$) from each other (Table 1). After 12 h of heating, the final TPC levels were: 15.01, 14.36, 14.09, and 13.40% in the samples roasted for 0, 1, 2, and 3 min. However, the total polar contents of perah samples did not exceed the limit 27% for used frying fats based on the German standard[33]. Roasting perah seed resulted in a marked decline in TPC of seed oil, thus showing enhancement of the oxidative stability of perah seed oil. The results obtained from tocol analysis indicate that roasting and heating greatly affect the content of the tocols in all analyzed samples. In the present study, roasting of seed leads to a noticeable increase in the tocopherol and tocotrienol contents. We assumed that the increase in tocols content was primarily due to the increased release of these compounds from the cell matrix. The similar trend was observed in the total tocopherol content when rapeseeds were roasted at 180℃[34]. Any increase in tocopherol and tocotrienol could be also due to the removal of moisture content during roasting in relation to the weight of the sample. On the other hand, tocols in PSOs were significantly decreased ($p<0.05$) at each heating period; however, tocols degradation was significantly less advanced in roasted samples during heating at 170℃. Observed phenomenon was probably due to the fact that high temperatures intensifies lipid oxidation reactions which contribute to the degradation of tocopherols during thermal processing[35]. Vaidya and Eun[36] reported that the tocopherol retention was higher in roasted walnut oil during storage in the dark at 60℃.

3.4 Changes in fatty acid composition (FAC)

As can be seen in Table 2, PSO fatty acids profile was dominant in oleic (33.78%) and linoleic (34.08%) acids followed by linolenic acid (15.57%), and then palmitic acid (13.21%). This profile is almost similar to that reported by Yong and Salimon[1] who studied same seed oil. Analyzing the fatty acids by their common nature, grouped according to their unsaturation degree, the most affected fraction was the PUFA, directly related with their higher number of double bonds, with higher susceptibility to oxidation[9, 33]. During roasting, the percentage of PUFA tended to decrease slightly, whereas the percentage of SFA increased slightly. This trend was probably due to PUFA degradation and was in good agreement with that reported by Vaidya and Choe[10]. In unroasted samples, the relative contents of PUFA decreased to 94.42%, while of SFA increased to 110.20% after 12 h heating (Table 3). There was a slight decrease of relative contents of PUFA in 3 min roasted samples to 98.08%, respectively, at the end of 12 h heating. On the other hand, relative contents of SFA in the samples roasted at 3 min increased slightly to 103.41%, respectively, at the same time. However, the change in relative contents of PUFA or SFA was high in raw samples compared to roasted ones throughout the heating period. These results

Table 1 Changes in colour, viscosity, total polar compound and tocols of perah seed oils during thermal oxidation.

Parameter	Roasting time (min)	Heating time (h)			
		0	4	8	12
Colour L*	0	62.80 ± 0.06^{dD}	57.93 ± 0.02^{cD}	54.70 ± 0.08^{bD}	50.39 ± 0.02^{aD}
	1	62.50 ± 0.07^{dC}	57.34 ± 0.07^{cC}	53.45 ± 0.03^{bC}	50.30 ± 0.04^{aC}
	2	58.49 ± 0.02^{dB}	56.02 ± 0.03^{cB}	52.92 ± 0.03^{bB}	51.47 ± 0.06^{aB}
	3	54.03 ± 0.02^{dA}	51.54 ± 0.02^{cA}	48.51 ± 0.04^{bA}	47.43 ± 0.04^{aA}
Colour a*	0	− 1.47 ± 0.01^{aA}	− 1.38 ± 0.02^{bA}	− 1.34 ± 0.01^{cA}	− 1.33 ± 0.01^{cA}
	1	− 1.39 ± 0.01^{aB}	− 1.37 ± 0.01^{aA}	− 1.37 ± 0.02^{aA}	− 1.23 ± 0.01^{bB}
	2	− 1.30 ± 0.01^{aC}	− 1.17 ± 0.03^{bB}	− 0.97 ± 0.02^{cB}	− 1.23 ± 0.01^{dB}
	3	− 1.17 ± 0.02^{aD}	− 1.12 ± 0.01^{bC}	− 0.94 ± 0.02^{cC}	− 0.90 ± 0.01^{dC}
Colour b*	0	7.00 ± 0.02^{aA}	8.20 ± 0.03^{bA}	9.03 ± 0.03^{cA}	10.13 ± 0.06^{dA}
	1	7.53 ± 0.03^{aB}	8.40 ± 0.04^{bB}	9.10 ± 0.02^{cB}	10.27 ± 0.01^{dB}
	2	8.00 ± 0.01^{aC}	8.70 ± 0.05^{bC}	9.50 ± 0.02^{cC}	10.30 ± 0.01^{dB}
	3	8.07 ± 0.04^{aD}	9.40 ± 0.03^{bD}	10.43 ± 0.03^{cD}	11.50 ± 0.06^{dC}
Viscosity (cP at 40℃)	0	32.90 ± 0.12^{aA}	35.60 ± 0.10^{bC}	37.02 ± 0.12^{cB}	40.53 ± 0.12^{dD}
	1	33.10 ± 0.15^{aA}	35.73 ± 0.11^{bC}	36.85 ± 0.21^{cB}	39.75 ± 0.22^{dC}
	2	33.80 ± 0.11^{aB}	35.17 ± 0.11^{bB}	36.47 ± 0.04^{cA}	39.34 ± 0.12^{dB}
	3	34.60 ± 0.14^{aC}	34.50 ± 0.10^{bA}	36.80 ± 0.06^{cB}	38.89 ± 0.11^{dA}
Total Polar Compound (%)	0	5.23 ± 0.03^{aA}	9.13 ± 0.03^{bC}	12.73 ± 0.03^{cD}	15.01 ± 0.05^{dD}
	1	5.46 ± 0.12^{aB}	9.42 ± 0.02^{bD}	11.39 ± 0.12^{cC}	14.36 ± 0.04^{dC}
	2	5.47 ± 0.07^{aB}	8.91 ± 0.05^{bB}	10.48 ± 0.05^{cA}	14.09 ± 0.07^{dB}
	3	5.59 ± 0.04^{aB}	7.88 ± 0.08^{bA}	10.82 ± 0.12^{cB}	13.40 ± 0.02^{dA}
Tocopherol (ppm)	0	93.32	81.18	58.45	18.45
	1	124.37	109.34	80.34	53.45
	2	129.56	123.35	115.82	88.34
	3	162.51	144.13	120.45	88.92
Tocotrienol (ppm)	0	62.43	61.82	39.47	nd
	1	64.32	57.24	56.16	40.37
	2	74.77	70.92	68.39	46.91
	3	80.28	69.19	66.14	45.49

Each value (except for tocols) in the table represents the mean of three replicates ± SD.
Means followed by different lowercase letters in the same row of individual parameter present significant difference ($p < 0.05$).
Means followed by different uppercase letters in the same column of individual parameter present significantly different ($p < 0.05$).
nd = Not detected

are in accordance with those reported for pumpkin seed[6] and mustard seed[10] oils during heating. Moreover, the ratio of polyunsaturated to saturated fatty acids (P/S) that implied a valid indicator of evaluating oil oxidation[37], of all samples declined with increasing heating time. The smallest change (decrease) in P/S ratio belonged to the roasted samples. This means that oxidation process progressed more rapidly in raw samples as compared to roasted ones during heating. In fact, the changes in fatty acids composition during thermal treatment was not as sharp as found in the pumpkin seed[6] and mustard seed[10] oils.

4 Conclusion

The present study provides an insight into understand-

Table 2 Fatty acid composition (%) of unroasted and roasted perah seed oils before thermal oxidation.

Fatty acids	Roasting time (min)			
	0	1	2	3
Lauric acid (C12:0)	0.07 ± 0.04	0.09 ± 0.03	0.06 ± 0.10	0.09 ± 0.04
Myristic acid (C14:0)	0.18 ± 0.03	0.12 ± 0.05	0.16 ± 0.02	0.12 ± 0.01
Palmitic acid (C16:0)	13.21 ± 0.01	13.56 ± 0.11	13.76 ± 0.05	13.84 ± 0.10
Palmitoleic acid (C16:1)	0.20 ± 0.05	0.09 ± 0.07	0.07 ± 0.01	0.07 ± 0.06
Stearic acid (C18:0)	2.74 ± 0.08	2.83 ± 0.02	2.91 ± 0.03	3.10 ± 0.01
Oleic acid (C18:1)	33.78 ± 0.02	33.58 ± 0.09	33.40 ± 0.03	33.28 ± 0.09
Linoleic acid (C18:2)	34.08 ± 0.04	33.94 ± 0.03	33.79 ± 0.04	33.74 ± 0.21
Linolenic acid (C18:3)	15.57 ± 0.13	15.55 ± 0.21	15.63 ± 0.17	15.64 ± 0.18
Arachidic acid (C20:0)	0.18 ± 0.03	0.2 ± 0.10	0.22 ± 0.03	0.14 ± 0.05
∑Saturated fatty acids	16.38 ± 0.04	16.83 ± 0.14	17.11 ± 0.08	17.29 ± 0.14
∑Monounsaturated fatty acids	33.98 ± 0.02	33.67 ± 0.09	33.47 ± 0.13	33.35 ± 0.19
∑Polyunsaturated fatty acids	49.65 ± 0.12	49.49 ± 0.13	49.42 ± 0.09	49.38 ± 0.13

Each value is the mean ± standard deviation of triplicate determinations.

Table 3 Changes in saturated, monounsaturated and polyunsaturated fatty acid composition of unroasted and roasted perah seed oils during thermal oxidation.

Roasting time (min)	Heating time (h)	Fatty acid composition (%)			
		Saturated fatty acids	Monounsaturated fatty acids	Polyunsaturated fatty acids	P/S
0	0	16.38 (100.00)	33.98 (100.00)	49.65 (100.00)	3.03
	4	16.98 (103.66)	35.26 (103.77)	47.76 (96.19)	2.81
	8	17.78 (108.55)	35.37 (104.09)	47.07 (94.80)	2.65
	12	18.05 (110.20)	35.02 (103.06)	46.88 (94.42)	2.60
1	0	16.83 (100.00)	33.67 (100.00)	49.49 (100.00)	2.94
	4	17.07 (101.43)	33.64 (99.91)	49.39 (99.80)	2.89
	8	17.92 (106.48)	33.91 (100.71)	47.97 (96.93)	2.68
	12	18.07 (107.37)	34.07 (101.19)	47.81 (96.61)	2.65
2	0	17.11 (100.00)	33.47 (100.00)	49.42 (100.00)	2.89
	4	17.25 (100.82)	33.58 (100.33)	49.25 (99.66)	2.86
	8	17.77 (103.86)	33.39 (99.76)	49.04 (99.23)	2.76
	12	18.04 (105.44)	33.23 (99.28)	48.87 (98.89)	2.71
3	0	17.29 (100.00)	33.35 (100.00)	49.38 (100.00)	2.86
	4	17.30 (100.06)	33.57 (100.66)	49.13 (99.49)	2.84
	8	17.64 (102.02)	33.52 (100.51)	48.83 (98.89)	2.77
	12	17.88 (103.41)	33.68 (100.99)	48.43 (98.08)	2.71

Number in parenthesis is relative % of saturated, monounsaturated and polyunsaturated fatty acids based on the initial saturated, monounsaturated and polyunsaturated fatty acids content before thermal oxidation. P/S- ratio of polyunsaturated to saturated fatty acids. Each value is the mean of triplicate determinations.

ing the impact of microwave roasting on the thermooxidative degradation of perah seed oil. By combining the knowledge of different assessment of oxidation parameters, it can be asserted that microwave roasting slowed down the oxidative deterioration of oil by improving its hydrolytic and tocols stability, inhibiting double bond conjugation and reducing the losses of polyunsaturated fatty acids. The highest increased or decreased amounts in different analytical values were observed for the perah oil extracted from raw seeds. In view of this finding, it can be inferred that use of microwave is a promising possibility to improve the stability and quality of PSO during heating at frying temperature. It is hoped that the data generated from this study may facilitate food manufacturers to decide on the suitable oils for their frying operation.

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