International Journal of GEOMATE, March, 2020, Vol.18, Issue 67, pp. 27-32
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.67.5567
Special Issue on Science, Engineering and Environment

EFFECT OF COMBINATION MICROWAVE AND OVEN DRYING ON THE CHEMICAL PROPERTIES OF DIFFERENT RIPENESS CRUDE PALM OIL

Mallika Tapanwong[1], Rayakorn Nokkaew[2] and *Vittaya Punsuvon[1,2]

[1]Faculty of Science, Kasetsart University, Thailand; [2]Center of Excellence-Oil Palm Kasetsart University, Thailand

*Corresponding Author, Received: 15 June 2019, Revised: 20 Nov. 2019, Accepted: 05 Dec. 2019

ABSTRACT: Small crude palm oil mill in Thailand produced the low quality of crude palm oil by using oven drying to dry palm fruits for 14-16 hours. So, the aim of this research is to replace oven drying by using the combined microwave and oven drying to dry palm fruits at different ripeness for 3-4 hours. The effects of combined methods on the chemical properties of crude palm oil are evaluated and compared the properties with premium crude palm oil. The experiments of study followed this detail. The raw materials were 18, 20, 22 and 24% of oil content consisted in oil palm bunches. In experiment, 1 kg of each sample was heated at 850 watt for 10 minutes in microwave followed with oven drying for 3 hours. Heated palm fruits were further separated the mesocarp from kernel seed. The mesocarp was further pressed by screw press to obtain crude palm oil. The oil was analyzed its chemical properties in term of free fatty acid (FFA), deterioration of bleachability (DOBI), carotene content, vitamin E content, iodine value (IV) and peroxide value (PV). The results showed that all of oil palm fruits ripeness can produce a premium crude palm oil with low free fatty acid content and high DOBI value.

Keywords: Microwave, Oven, Oil palm fruit, Ripeness

1. INTRODUCTION

At the present, large and medium scale palm oil mills in Thailand were used a steam sterilization process which has pressurized the palm bunches of 15-45 psi for 90 min at a temperature more than 100 ^{o}C. Crude palm oil obtained from this process has a good quality. Nevertheless, effective steam sterilization process has produced many wastewater because of the large amount water used in the process. Thus, the high cost of discharge treatment was necessary to rigorous environmental standard [1]. Most small-scale mills in Thailand do not have more ability to generate steam for sterilization. Therefore, non-steam sterilization of the bunch such as drying by hot air is alternative process. But the disadvantage of this process is getting lower quality of crude palm oil due to excessive temperature and long drying time of operation.

Microwave is electromagnetic waves with wavelengths ranging from 1 nm to 1 m, or frequencies between 0.3 GHz to 300 GHz. Industry utilizes microwave energy as a source of energy for heating and sterilization [2]. The mechanism of heat generation in the palm oil fruit at a microscopic level is due to the re-orientation of water molecules in the palm fruit to follow electric field direction and interact among themselves which creates friction and heat. The temperature rises of oil palm fruit that exceed 47 ^{o}C enhance reduction or inhibition of lipase enzyme activity [3]. Several studies reported the utilization of microwave to heat and sterilize oil palm fruit follow these details. Cheng [4] found that the quality of the crude palm oil produced by microwave pretreatment followed with solvent extraction was superior compared to that produced by using conventional means in terms of lower acidity, lower moisture content, higher carotene content and higher vitamin E content. Tan [5] studied the combined process of microwave pretreatment and solvent extraction in the laboratory scale and found that this process gave high yield of palm oil, low free fatty acid content, low peroxide value, low anisidine value and high carotene content of the obtained palm oil. Chow [6] studied the detachment of palm fruits from whole bunches and spikelets using microwave heating. The result showed that microwave heating had high sufficiently detached the palm fruits from both whole bunches and spikelets in the easy way by using a slight push of the finger. Sarah [2] studied the effect of sterilization time and temperature on fatty acids composition, carotene and vitamin E content of oil extracted from palm fruit that irradiated by microwave energy. The results showed that fatty acids composition and vitamin E content were not influenced by time and temperature increment but carotene content greatly influenced by temperature increment.

Our studied replaced the drying palm fruit by hot air into microwave for sterilization of palm fruit and we found that microwave drying can inactivated the lipase enzyme activity that result in decreasing of the

free fatty acid in crude palm oil. In addition, the deterioration of bleachability index (DOBI) value, carotene content in crude palm oil increase after microwave drying of palm fruit, too. However, the drying by microwave is not enough to decrease the moisture content in palm fruit to less than 10 %w/w that is suitable for screw pressing. Thus, the palm fruit obtained after microwave drying need to decrease the moisture content by drying again with hot air in oven drying for a few hours.

The aim of this research is to determine the effect of palm fruit ripeness on the quality that obtained after drying by microwave combined with oven drying. Oil quality in term of chemical properties measured were free fatty acid content (FFA), DOBI, peroxide value (PV). Iodine value (IV), carotene content and tocopherol content. DOBI and FFA of the obtained crude palm oil from different ripeness are compared with the premium crude palm oil standard, too.

2. MATERIAL AND METHOD

2.1 Material

Fresh palm fruit bunch at the different ripeness of 18, 20, 22 and 24% based on oil content of bunch were collected from local oil palm plantation in Pangnga province, Thailand. Fresh fruit bunches were chopped into fruit spikelets and 1 kg of each piece was weighed for microwave drying.

2.2 Microwave and Oven Drying Experiments

1 kg of fruit spikelet was weighed before undergoing microwave drying (microwave oven sharp model with maximum power output of 850 W at 2,450 MHz) for 10 minute intervals time until 100% stripping reach. The fruit at the spikelets were detached with a slight push of a finger until the fruits were completely detached from the spikelet. The detached palm fruit were kept at room temperature for one night after that they were dried in oven at 70-75 ^{o}C for 3 hours. After the drying process, the mesocarp of the fruit was peeled and the seeds were removed. The peeled mesocarp was pressed using screw press to extract the oil and the oil was collected for its chemical analysis. The drying, extraction and analysis of this experiment is shown in Fig. 1.

2.3 Determination of Free Fatty Acid Content (FFA)

The FFA content of the oil sample was measure by dissolving oil in 95% ethanol and titrated with 0.1 N sodium hydroxide solution using a phenolphthalein indicator. A blank determination was also made with the sample procedure without the oil sample. The percentage of FFA content was calculated using this Eq. (1).

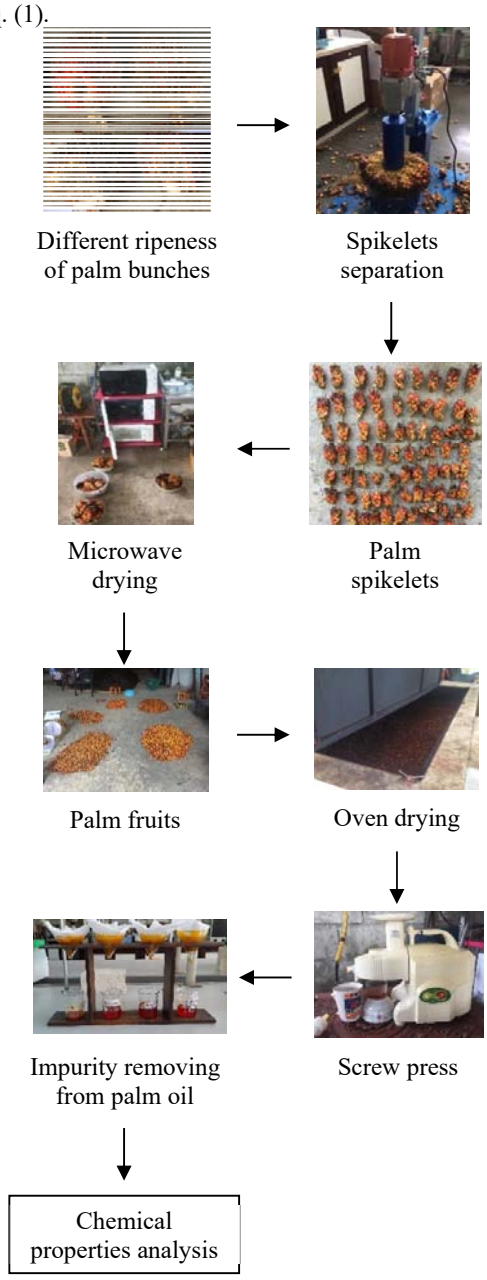

Fig. 1 The experimental diagram of drying, extraction and analysis

$$\text{FFA}\ (\%) = \frac{(\text{S} - \text{B}) \times \text{N} \times 25.6}{\text{W}} \qquad (1)$$

Where, S is the volume of sodium hydroxide used for oil titration, B is the volume of sodium hydroxide used for blank titration, N is the concentration of sodium hydroxide, W is the weight of oil.

2.4 Determination of Peroxide Value (PV)

A 5 g oil sample was dissolved in a 30 ml mixture

of acetic acid and chloroform which was further reacted with 0.5 ml of saturated potassium iodine solution. After one minute of shaking, 30 ml of water were added and the contents were shaken vigorously to liberate iodine from the organic to aqueous layer. Iodine was titrated with a 0.1 N sodium thiosulphate solution using a starch indicator. A blank determination was made using the same procedure without the oil sample. PV was calculated using the Eq. (2) (AOCS official method cd 8-53, 1997)

$$\mathrm{PV} = \frac{(\mathrm{S} - \mathrm{B}) \times \mathrm{N} \times 1000}{\mathrm{W}} \quad (2)$$

Where, S is the volume of sodium thiosulphate used to titrate with oil sample, B is the volume of sodium thiosulphate used to titrate with blank, N is the concentration of sodium thiosulphate, W is the weight of oil.

2.5 Determination of Iodine Value (IV)

IV was determined followed AOCS official method cd 1-25. Briefly explained, 0.2 g of oil sample was weight into 250 ml of iodine flask. Then, 10 ml of chloroform and 25 ml of wijs reagent was added to into a flak, respectively. The analytical flask was shaken vigorously and stored in a dark place for 2 hours. After that, the flask was added with 20 ml of potassium iodide followed with 15 ml of distillated water. The sample solution was titrated immediately with 0.1 N sodium thiosulphate until yellow color almost disappears. A starch indicator was added into sample and titrated continuously until the blue starch-iodine color disappeared. In addition, a blank was made in the same manner. The IV value is calculated followed Eq. (3)

$$\mathrm{IV} = \frac{(\mathrm{B} - \mathrm{S}) \times \mathrm{N} \times 12.69}{\mathrm{W}} \quad (3)$$

Where, B is the volume of sodium thiosulphate used to titrate with blank, S is the volume of sodium thiosulphate used to titrate with oil sample, N is the concentration of sodium thiosulphate, W is the weight of oil.

2.6 Determination of Carotene Content

Carotene content were carried using MPOB test method (2004). Briefly explained, 0.1 g of oil sample was dissolved in n-hexane in a 25 ml volumetric flask. The absorbance reading of the solution at 446 nm was taken using UV-VIS spectrophotometer. The carotene content is calculated as Eq. (4).

$$\text{Total carotene content (ppm)} = \frac{383(\mathrm{A})(\mathrm{V})}{100(\mathrm{W})} \quad (4)$$

Where, A is the absorbance at 446 nm, V is the volume of oil solution (25 ml) and W is the weight in gram of oil sample.

2.7 Determination of Deterioration of Bleachability Index (DOBI)

DOBI was determined followed MPOB test method (2004). DOBI is defines as the ratio of the spectrometric absorbance at 446 nm to 269 nm. Briefly explained, 0.1 g of oil sample was weighed into 25 ml of volumetric flask and dissolved with n-hexane. The sample solution was measured absorbance at 269 and 446 nm using UV-VIS spectrophotometer. The value of DOBI is calculated followed Eq. (5)

$$\mathrm{DOBI} = \frac{\text{Absorbance at 446 nm}}{\text{Absorbance at 269 nm}} \quad (5)$$

2.8 Determination of α-tocopherol and γ-tocotrienol by HPLC

A 20 µl of oil sample (obtained by solubilizing 250 mg of oil in 25 ml of n-hexane) was directly injected to a HPLC column 15cm x 4.6 mm ID (Unison UK-Silica UK505, Imtakt, USA) at a flow rate of 1 ml/min and 292 nm of wavelength. The HPLC system for α-tocopherol and γ-tocotrienol content analysis consisted of Yonglin-HPLC equipped UV detector. Standard solution of α-tocopherol and γ-tocotrienol were used at 0-150 pm concentration for quantification. The mobile phase was 99.5% n-hexane and 0.5% isopropanol which was HPLC grade.

2.9 Statistical Analysis

All independent parameter were carried out in triplicated and the result were expressed as the mean value. Data were statistically analyzed by analysis of variance (ANOVA) followed by Duncan test. The significant level of difference between chemical properties from different ripeness of oil palm bunch were accessed. The level of significance is $p<0.05$.

3. RESULTS AND DISCUSSION

3.1 Effect of Drying Process on FFA Content

A FFA content of each sample is shown in Table 1. The results indicated that the microwave combined with oven drying could reduce the FFA content of all ripeness. Due to the lipase enzyme which induces the hydrolysis reaction of triglyceride to generate the FFA is inactivated by microwave and oven. The results showed that the drying process affected to reduce the FFA content while the different ripeness at the same drying step was not affected. The statistical

analysis showed that the FFA content was not significant difference in all experiment. In addition, the FFA content in all ripeness of palm fruits after oven drying were 1.08-1.65 %w/w.

Table 1 The relationship of FFA on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average FFA (%w/w)			
	Raw material	MW*	Left for 1 night	After oven drying
18	28.80[a]	4.69[b]	2.21[b]	1.08[b]
20	28.41[a]	3.26[b]	1.25[b]	1.28[b]
22	30.76[a]	4.17[b]	1.69[b]	1.63[b]
24	28.43[a]	2.87[b]	1.64[b]	1.65[b]

*MW means after microwave drying
[a-b] Denotes statistically significant in a same row (P<0.05)

3.2 Effect of Drying Process on Carotene Content and DOBI

The total carotene content was shown in Table 2. The result showed that the carotene content increased after microwave drying. The carotene content was slightly decreased after left for one night and after oven drying. The obtained carotene content in all ripeness of palm fruits after oven drying were 554.7-731.5 ppm. The statistical analysis showed that the carotene content was not significant different in all experiment of different ripeness of oil palm fruits.

Table 2 The relationship of total carotene content on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average total carotene content (ppm)			
	Raw material	MW*	Left for 1 night	After oven drying
18	396.2	610.2	598.4	554.7
20	411.8	682.3	755.3	639.2
22	599.0	689.4	714.8	646.0
24	699.7	742.7	704.0	731.5

*MW means after microwave drying

In addition, The DOBI of the oil after treatment was affected by drying process (Table 3). The results indicated that DOBI value of all ripeness increased when the sample were treated by microwave and kept constant though left for one night or oven drying. The statistical analysis showed that DOBI value was not significant different in all experiment of different ripeness of oil palm fruit. The obtained DOBI value in all ripeness of palm fruits after oven drying were 3.89-4.61.

Table 3 The relationship of DOBI on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average DOBI			
	Raw material	MW*	Left for 1 night	After oven drying
18	1.05[b]	4.07[a]	4.10[a]	3.89[a]
20	1.74[b]	4.49[a]	4.83[a]	4.61[a]
22	2.05[b]	4.75[a]	4.78[a]	4.18[a]
24	2.17[b]	4.31[a]	4.29[a]	4.00[a]

*MW means after microwave drying
[a-b] Denotes statistically significant in a same row (P<0.05)

3.3 Effect of Drying Process on Peroxide Value

The peroxide value which represents the first oxidation reaction is shown in Table 4.

Table 4 The relationship of peroxide value on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average peroxide value (meq O_2/kg oil)			
	Raw material	MW*	Left for 1 night	After oven drying
18	5.5[a]	1.5[b]	1.7[b]	0.4[b,C]
20	0.2[b]	0.7[a]	0.6[a]	0.8[a,BC]
22	1.2	0.9	1.8	1.4[B]
24	3.8	2.3	2.7	2.5[A]

*MW means after microwave drying
[a-b] Denotes statistically significant in a same row (P<0.05)
[A-C] Denotes statistically significant in a same column (P<0.05)

In comparison of drying process, the statistical analysis investigated that the microwave drying had affected on peroxide value at 18 and 20% of oil content while the other was not. The peroxide value of palm oil after microwave treatment was decreased from raw material at 18% of oil content. In 20% of oil content, the result was contrast with 18% of oil content. The peroxide value increased when the sample was treated by microwave. Due to the microwave can induce the peroxide species on unsaturated fatty acid molecule in palm oil. In oven drying, the peroxide value increased when the ripeness was increased. The obtained PV value in all ripeness of palm fruits after oven drying were 0.4-2.5 meq O_2/kg oil.

3.4 Effect of Drying Process on Iodine Value

The iodine value represents the number of unsaturated species. Table 5 indicated that the drying process wasn't affected on iodine value for all ripeness.

Table 5 The relationship of iodine value on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average iodine value (g I_2/100 g oil)			
	Raw material	MW*	Left for 1 night	After oven drying
18	53.5	54.0	54.0	52.0^{B}
20	56.9	56.2	56.8	55.9^{A}
22	53.5	54.5	53.7	52.8^{B}
24	54.0	54.2	53.8	53.3^{B}

*MW means after microwave drying
A-B Denotes statistically significant in a same column (P<0.05)

However, the statistical analysis showed significant difference of iodine value on different ripeness. For palm oil after oven drying, the highest iodine value was 20% of oil content because of high originated amount. The obtained iodine value in all ripeness of palm fruits after oven drying were 52.0-55.9 g I_2/100g oil.

3.5 Effect of Drying Process on α-tocopherol Content

Crude palm oil is the one of vitamin E resources which contained about 600-1000 ppm. A vitamin E in palm oil consists of both tocopherol (21.3%) and tocotrienol (78.7%) [7]. A beneficial of vitamin E is antioxidant characterization that prevents the oxidation reaction of oil. In this study, the vitamin E in the form of α-tocopherol was study and shown in Table 6.

Table 6 The relationship of α-tocopherol content on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average α-tocopherol content (ppm)			
	Raw material	MW*	Left for 1 night	After oven drying
18	$1,248^{a,A}$	$920^{b,A}$	$967^{b,A}$	$911^{b,A}$
20	$933^{a,B}$	$781^{b,B}$	$784^{b,B}$	$798^{b,B}$
22	811^{B}	744^{B}	739^{B}	715^{BC}
24	803^{B}	722^{B}	737^{B}	740^{C}

*MW means after microwave drying
a-b Denotes statistically significant in a same row (P<0.05)
A-C Denotes statistically significant in a same column (P<0.05)

The α-tocopherol content of sample after drying process indicated that the microwave had affected to reduce the amount of α-tocopherol content. In the ripeness comparison, the 18% of oil content gave the highest α-tocopherol content and decreased when the oil content was increased. For γ-tocotrienol, the result gave the same trend of α-tocopherol (Table 7). The γ-tocotrienol decreased when the sample was treated by microwave but the ripeness was insignificant difference. The obtained α-tocopherol content in all ripeness of palm fruits after oven drying were 715-911 ppm.

Table 7 The relationship of γ-tocotrienol content on the different ripeness of oil palm fruits at different condition of experiment

Ripeness based on %oil content	Average γ-tocotrienol content (ppm)			
	Raw material	MW*	Left for 1 night	After oven drying
18	719^{a}	64^{b}	27^{b}	-
20	474^{a}	32^{b}	$24^{b,c}$	13^{c}
22	727^{a}	41^{b}	8^{b}	20^{b}
24	809^{a}	17^{b}	12^{b}	19^{b}

*MW means after microwave drying
a-b Denotes statistically significant in a same row (P<0.05)

However, γ-tocotrienol was more decreased by drying treatment than α-tocopherol. The almost 90% of γ-tocotrienol was destructed by microwave whereas α-tocopherol was lost about 15-30% in this process. The reason might be molecular structural difference between both forms. The structure of both vitamin E forms have the same chromanol ring but it differ at the position of the side chain. The unsaturated side chain of γ-tocotrienol is more sensitive to microwave heating than α-tocopherol consisting saturated side chain. Thus, γ-tocotrienol are easily destroy. The obtained γ-tocotrienol content in all ripeness of palm fruits after oven drying were 13-19 ppm.

3.6 Comparison of Crude Palm Oil with Premium Crude Palm Oil

The obtained quality of crude palm oil from different ripeness of palm fruits were compared with the quality of premium crude palm oil from the study of [5]. The results were shown in Table 8. It showed that all DOBI value of crude palm oil from different ripeness met the DOBI value of premium crude palm oil. For FFA, only the ripeness at 18% met the FFA of premium crude palm oil but the FFA from the ripeness at 20%, 22% and 24% were a little bit higher

than FFA of premium crude palm oil.

Table 8 Quality comparison of crude palm oil from different ripeness with premium crude palm oil

Quality	Crude palm oil from different ripeness at				Premium crude palm oil
	18%	20%	22%	24%	
FFA (%w/w)	1.08	1.28	1.63	1.65	1.19
DOBI	3.89	4.61	4.18	4.00	3.20

4. CONCLUSIONS

Microwave is one of several technique to improve the quality of crude palm oil but this technique consumes the high production cost. Thus, the combination between microwave and oven drying are the better choice for crude palm oil production. Our study showed that crude palm oil obtained from different ripeness (18-24%) of this technique had FFA, total carotene content, DOBI, PV, IV, α-tocopherol and γ-tocotrienol equal 1.08-1.65 %w/w, 554.70-731.50 ppm, 3.89-4.61, 0.4-2.5 meq O_2/kg oil, 52.0-55.9 g I_2/100g oil, 715-911 ppm and 13-19 ppm, respectively. These obtained crude palm oil had less value of FFA and high value of DOBI that met the standard of premium crude palm oil.

5. ACKNOWLEDGMENTS

This research was supported by Tech Enterprise Service Network (TESNet), Center of Excellence-Oil Palm, Kasetsart University and Department of Chemistry, Faculty of Science, Kasetsart University.

6. REFERENCES

[1] Umudee I., Chongcheawchamnan M., Kaitweerasakul M. and Tongurai C., Sterilization of Oil Palm Fresh Fruit Using Microwave Technique. International Journal of Chemical Engineering and Applications, Vol. 4, Issue 3, 2013, pp.111-113.

[2] Sarah M., Ramadhan M.R. and Zahra A., Effect of Sterilization Time and Temperature on Fatty Acids, Carotenoids and Vitamin E of Oil Extracted from Palm Fruit Irradiated by Microwave Energy. Proceedings of the 4th International Symposium on Applied Chemistry, 2018, pp.020068-1 – 020068-8.

[3] Sarah M., Widyastuti S. and Ningsih D., Red Palm Oil Production by Microwave Irradiation. IOP Conference Series: Materials Science and Engineering, Vol. 309, 2018, pp.1-5.

[4] Cheng S.F., Mohd N.L. and Chuah C.H., Microwave Pretreatment: A Clean and Dry Method for Palm Oil Production. Industrial Crops and Products, Vol. 34, 2011, pp.967-971.

[5] Tan J. CX., Chuah C.H. and Cheng S.F., A Combined Microwave Pretreatment/Solvent Extraction Process for the Production of Oil from Palm Fruit: Optimisation, Oil Quality and Effect of Prolonged Exposure. Journal of the Science of Food and Agriculture, Vol. 97, 2017, pp.1784-1789.

[6] Chow M.C. and Ma A.N., Processing of Fresh Palm Fruits Using Microwaves. Journal of Microwave Power and Electromagnetic Energy, Vol. 40, Issue 3, 2007, pp.165-173.

[7] Kua Y.L., Gan S., Morris A. and Ng H.K., Optimization of Simultaneous Carotenes and Vitamin E (Tocols) Extraction from Crude Palm Olein Using Response Surface Methodology. Chemical Engineering Communications, Vol. 205, Issue 5, 2018, pp.596-609.

[8] Erkan, N., Ayranci G. and Ayranci, E., A Kinetic Study of Oxidation Development in Sunflower Oil under Microwave Heating: Effect of Natural Antioxidant. Food Research International, Vol. 42, Issue 5, 2009, pp. 1171-1177.

[9] Bonnie, T.Y.P. and Choo, Y.M., Oxidation and thermal degradation of carotenoids. Journal of oil palm research, Vol. 11, Issue 1, 1999, pp. 62-78.

[10] Chow, M.C., Ma, A.N., Processing of fresh palm fruits using microwaves. Journal of microwave power and electromagnetic energy. Vol. 40, Issue 3, 2007, pp. 165-173.

[11] Vincent, C.J., Shamsudin, R., Baharuddin, A, S., Pre-treatment of oil palm fruits: A review. Journal of food engineering, Vol. 143, 2014, pp. 123-131.

[12] Kasmin, H., Lazim, A.M., Awang, R., Effect of heat treatments on the yield, quality and storage stability of oil extracted from palm fruits. Malaysian journal of analytical science, Vol. 20, Issue 6, 2016, pp. 1373-138.

[13] Sarah, M., Carotenoids preservation during sterilization of palm fruit using microwave irradiation. ARPN journal of engineering and applied sciences, Vol. 13, Issue 3, 2018, pp. 1009-1014.