Effects of Microwave Sterilization Pre-Treatment Conditions on Crude Palm Oil Quality

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***Abstract*— Microwave sterilization pre-treatment conditions give direct effects to the crude palm oil quality. Its operating power and the ratio of water to the palm fruit spikelets are the variables that being manipulated in this study. Extraction of oil from the fresh fruit bunch is basically the practice adapted for the result analysis to be obtained. The power of the operation and the ratio to the water weight of every sample however are variables being manipulated in this particular case. Analyses of the samples are done through oil yield and Free Fatty Acid (FFA) consideration. In short, products of less FFA content and high oil product yield are a preferable attribute for quality productions. In this particular experimental study, the lowest FFA composition content and highest yield of oil produced are averagely of ratio 1:1 with 1000W operation power; with FFA content composition only at amount of 0.2278 and oil yield of 0.6263 in g/g of feed and oil product compared to its highest FFA composition content of 0.4608 and oil yield of only 0.2083 mainly attributed from less ratio composition of 1:0 and 1:0.5 and low operating power averagely between 600-800W. These data results proved that conditions of the microwave sterilization pre-treatment indeed impact the quality of crude palm oil produced.**

Keywords*— Microwave, palm fruit, sterilization, Soxhlet extraction, rotary evaporator, operating power, ratio, free fatty acid (FFA).

I. INTRODUCTION

Palm oil industry products based on past-year records show a quick growth in its wide market demand including food, cosmetics, hygiene product and biofuel through its residue processing (Jundika *et al*., 2016). It contributed to 36.1% of the world's total oils and fats in 2007-2008 (Mielke, 2008). From 1950s to 2005, the average palm oil production had been rapidly elevated multiple times throughout the period; moreover, it had replaced the soybean oil as the most consumed edible oil worldwidely (Sime Darby Plantation, 2014). This incredible demand was believed caused for its affordable price, its production effectiveness and its high oxidative stability (Jundika *et al*., 2016). Thus, a more advance study on the method of enhancing this palm oil sector of production indeed best to be carried out for business survival purposes.

Consideration on the engineering-based knowledge support of the study on this particular mission of enhancing palm oil quality and production however need to be taken seriously as well. Studies and modification on the existing conventional palm oil processing are examples of the best way to start. Besides, studies on the past researchers techniques and method of conquering problems that arise also is an excellent alternative to attain the goal of this studies.

Several past researchers had done their studies on the palm oil quality enhancement through multiple methodologies including the emphasize of the sterilization aspects (Umudee *et al.*, 2013) and some did on the chopping of palm fruit effect (Fatin *et al.*, 2014) while others even prioritized on the parameters of process operation (Noerhidajat *et al.*, 2016). Possibilities on this study vary in many ways concerning a single goal; desiring high palm oil product quality through simplest and effective process.

Particular on this study, microwave sterilization pre-treatment condition were considered for the palm oil production process. The objective of this research based on the topic is to identify the factors that affect the crude palm oil quality. Besides that, it is also carried out for the determination of the effects of the microwave sterilization pre-treatment conditions on the crude palm oil quality.

II. METHODOLOGY

A. Materials

Fresh palm fruit for this experimental study was collected randomly from a farm located somewhere in Meru, Klang. The fruit collected needs to be in good condition, preferably without harsh scratch and bruises. It was then cut into smaller pieces in spikelets form by the use of steel pruning scissor within 24 hours after it was being cut from the tree. Spikelets were packed in small plastic packaging, respectively weighing approximately around 200g before being kept in the freezer while waiting for further experimental procedures to take place.

B. Microwave Sterilization

The spikelets of fresh palm fruit were rinse with water before being placed in the microwave for 3-minutes thawing. Thawing was done to freshen up the fruit from any presence of icy water as it was just brought out from the freezer.

Microwave sterilization pre-treatment was done on a Panasonic NN-ST651M microwave system and will be varied in operation power and the ratio of the water weight to the spikelets'. The operating powers were 600 W, 800 W and 1000 W while the ratios were 1:0, 1:0.5 and 1:1. Since all the variables were being considered and duplicated, thus, there were 18 samples altogether being conducted in this experiment as tabulated in Table 1.

Before every pre-treatment, all samples were weighed to obtain their respective current weight. Samples were then sterilized under their microwave parameters condition before being slightly-push of their fruits for the stripping efficiency determination. The sterilization and 'slight-push' practice were repeated until each spikelet left with no fruits attach to it. The fruits were then been cut in half for the physical appearance analysis before being packed in a plastic packaging and kept inside a freezer.

C. Oil Extraction

Palm fruits oil extraction was done by the use of Soxhlet extraction method. Before the process was proceeds, all samples however undergone a 24-hour drying inside an oven of temperature 103.5°C. Drying of the palm fruit is vital as it removes any water or liquid composition that may present within the fruit to ensure the purity of the sample, besides achieving a more effective oil extraction.

After drying, Soxhlet extraction procedure then took place. Equipment was set up and being prepared for each of the samples to be extracted. The weights of samples deposited in the timble of the Soxhlet extraction were recorded respectively. The solvent used for the oil extraction was hexane. As a result, the Soxhlet extraction then produced mixture of palm oil extract as well as composition of hexane and water at the end of the respective extraction process.

To remove out and separate the water and hexane compositions from the oil extract, all the samples were evaporated in a Heidolph Laborota 4000 efficient rotary evaporator; in order for the separation to take place. Thus, crude palm oil were then obtained and weighed before being kept in small bottles container. The samples were then kept inside a chiller.

D. Characterization of Palm Oil

After the oil extraction through Soxhlet extraction and rotary evaporation, the oil yield was analyze by considering the final respective weight of oil produced after the rotary evaporation and the weight of samples deposited in the timble. Thus, oil yield for the respective samples was obtained, tabulated and presented in graph form.

Besides, the samples of crude palm oil also were analyzed using the Varian 450-GC and Varian 240-MS Gas Chromatography-Mass Spectrometry (GC-MS) equipment. This analysis aims to determine the composition of Free Fatty Acid present within the samples. However, for the GC-MS analysis, only the average reading was being considered; where 5 samples were chosen which are samples labeled 1, 5, 10, 14 and 18. They were left to be in room temperature before being injected in vials containing 0.5mL of hexane solvent respectively. Each sample was injected into the vial in the amount of 0.5mL. GC-MS were then took its role analyzing the samples by using hexane as its reference solvent.

E. Free Fatty Acid (FFA)

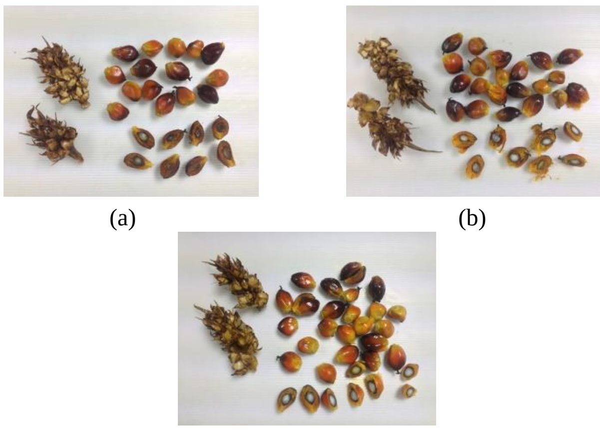
Titration process was the last experimental procedure being conducted in this study. All samples' mixture was titrated by potassium hydroxide (KOH) of concentration 0.1N. For the titration preparation, 2 g of sample were deposited in a conical flask before 25mL of isopropyl alcohol were added. The mixture was then slight stirred to dissolve them fully before 25mL more of isopropyl alcohol was added. 3 drops of phenolphthalene were then added in the conical flask. Titration of 0.1N KOH was then directed to the mixture until colour change from yellow to reddish-pink was observed. Volume of 0.1N KOH needed for the colour change of each sample to occur was recorded.

III. RESULTS AND DISCUSSION

A. Physical Appearance

Typical fresh palm fruits will consist of its mesocarp which looks like a fibrous flesh and its seed known as the kernel. The mesocarp appeared to be in yellowish-orange colour, giving out sweet odour while the kernel appeared to be very hard and white in colour. However, the appearance and conditions of these palm fruits' inner component were altered for every sample experiment for all respective parameters.

The conditions and appearances of palm fruits being treated at same operating power of 1000W but different ratios which are 1:0, 1:0.5 and 1:1 were depicted in Figure 1. From the observation of the figure, the drying of the fruits as well as the effects to the mesocarp in its structure and colour were affected directly by the ratio of the water to the palm fruit treated through microwave sterilization pre-treatment. The mesocarp condition of palm fruit treated under ratio of 1:0 appeared to be very hard, dry and obvious colour desaturation (browning). Its kernel also appeared to undergo browning and cracking. Mesocarp and kernel appeared to be fresher for the palm fruits treated in the ratio condition of 1:0.5. Their mesocarp did not appear to be so dry and hard in structure and its colour did not undergo browning. Their kernel seemed to be in yellowish colour. Meanwhile, palm fruits treated with ratio of 1:1 appeared to look very fresh. Its mesocarp visibly looks in glowing yellowish-orange eventhough its structure were soft and wet. Its kernel came into view looking still freshly white and firm in its structure.



(a) (b)

(c)

Fig.1: Physical appearance of palm fruits treated under microwave of same operating power of 1000W with varies ratios.
(a) Ratio 1:0 (b) Ratio 1:0.5 (c) Ratio 1:1

Meanwhile, for the physical appearance analysis considering same ratio but different microwave operating power of 600W, 800W and 1000W be found to have the same trend as the result mentioned above; where same operating power but different ratio of palm fruits to the water weight were considered. For the different operating power of same ratio sterilization pre-treatment, the fruits appeared to look really fresh for the 1000W operating power compared to the dry and hard condition of the mesocarp of operating power of 600W. Both shows a trends of physical effects on the palm fruits either they become dry and hard or wet and soft of their mesocarp obvious appearance while the various degree of browning of its kernel under particular conditions. Throughout the pre-treatments, caramel-like aroma was able to be smelt for all exposure duration.

B. Stripping Efficiency

All spikelets were pre-treated by their respective parameters and stripped by slightly push the palm fruit after each run of duration 2 minutes. The numbers of palm fruit leaving and remained on the spikelet for each run were recorded and the pre-treatment were done until all the fruits were completely removed from the spikelet's shaft.

Table 1 shows the stripping efficiency of each run for all the samples. From the table, as the data went down the table which implies the operation of the experiment were proceeds by their increase of operating power, the number of run to be conducted became lesser. It is also obvious that the trend of all the ratios proved greater microwave sterilization operating power will result less number of run to be operated as leaving amount of fruits is large in each run; implication of high stripping efficiency. Instigate stripping efficiency implied that the sterilization pre-treatment is favorable as it consumes less operating time as well as efficient palm fruits oil content restoration, considering it did not evaporate them out.

Table 1: Stripping efficiency of each sample of different ratios.

(a) Ratio 1:0

Label	Power (W)	Time (min)	F_{Ro}	F_R	F_L	Stripping efficiency (%)
1	600	2	11	11	0	0
		4	11	0	11	100
2		2	22	3	19	86.36
		4	3	0	3	100
3	800	2	22	14	8	36.36
		4	14	0	14	100
4		2	23	0	23	100
5	1000	2	20	0	20	100
6		2	19	0	19	100

(b) Ratio 1:0.5

Label	Power (W)	Time (min)	F_{Ro}	F_R	F_L	Stripping efficiency (%)
7	600	2	24	23	1	4.17
		4	23	19	4	17.39
		6	19	1	18	94.74
		8	1	0	1	100
8		2	18	17	1	5.56
		4	17	10	7	41.18
		6	10	1	9	90
		8	1	0	1	100
9	800	2	25	22	3	12
		4	22	16	6	27.27
		6	16	9	7	43.75
		8	9	1	8	88.89
		10	1	0	1	100
10		2	23	23	0	0
		4	23	15	8	34.78
		6	15	0	15	100
11	1000	2	18	17	1	5.56
		4	17	0	17	100
12		2	28	28	0	0
		4	28	3	25	89.29
		6	3	0	3	100

(c) Ratio 1:1

Label	Power (W)	Time (min)	F_{Ro}	F_R	F_L	Stripping efficiency (%)
13	600	2	24	24	0	0
		4	24	19	5	20.83
		6	19	6	13	68.42
		8	6	0	6	100
14		2	23	20	3	13.04
		4	20	12	8	40
		6	12	4	8	66.67
		8	4	0	4	100
15	800	2	26	24	2	7.69
		4	24	17	7	29.17
		6	17	7	10	58.82
		8	7	0	7	100
16		2	23	16	7	30.43
		4	16	2	14	87.50
		6	2	0	2	100
17	1000	2	22	20	2	9.09
		4	20	13	7	35
		6	13	0	13	100
18		2	27	17	10	37.04
		4	17	0	17	100

C. Oil Yield

In this study, Soxhlet extraction responsibles for the oil extraction from the palm fruits which has been pre-treated through microwave sterilization at particular conditions. Rotary evaporation then was used to completely extract the oil from its solvent to obtain the oil produced. Therefore, all samples underwent these steps, resulting the weight of oil produced tabulated in Table 2.

The table however did not gives out a consistent trend of data; where the weight of the samples was not in orderly trend; either increasing or decreasing. This may happened due to unstable oil extraction performance during the Soxhlet extraction or the unfix duration of evaporation as different extraction results a different composition of solvent hexane and oil in the mixture.

Table 2: Weight of palm fruit deposited in the timble and weight of oil produced by respective samples.

Label	Ratio	Power (W)	Weight of palm fruit deposited in the timble (g)	Weight of oil produced (g)
1	1:0	600	20.3220	6.1093
2			16.4222	5.1955
3		800	18.2507	5.7596
4			15.9153	6.2231
5		1000	20.8344	5.7795
6			18.4635	3.8458
7	1:0.5	600	17.9700	4.8349
8			19.6640	5.3186
9		800	19.9402	6.0566
10			20.5093	7.3456
11		1000	19.2640	6.4485
12			19.1549	5.5096
13	1:1	600	19.1909	6.8258
14			19.9105	8.8341
15		800	17.4504	5.8034
16			18.7318	5.7934
17		1000	19.4899	5.4022
18			16.7418	10.4330

Oil yield of each samples were then been calculated by the use of the information from Table 2. By using the oil yield formula, graph in Figure 2 was obtained. From Figure 2, it can be observe that the best parameter for oil yield is the operating condition of ratio 1:1 of power 1000W with value of 0.6263. The least oil yield condition is at ratio 1:0 of 1000W with value only at 0.2083. Clearly, high yield of oil produce is more desired in oil production; thus, it can be concluded that ratio of 1:1 of high operating power condition is recommended for better oil extraction efficiency as supported by Maya Sarah[4] in her research findings.

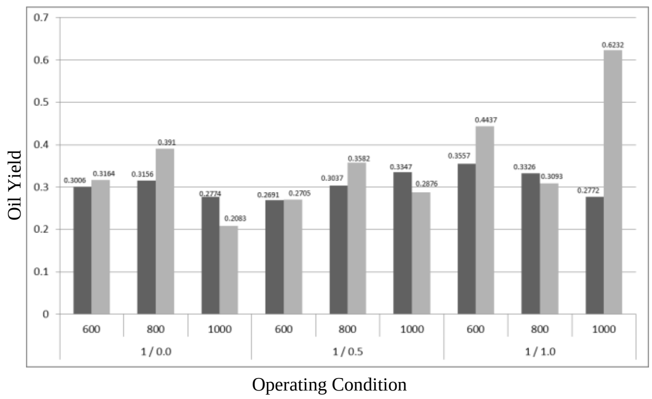


Fig. 2: Oil yield of all samples.

D. Free Fatty Acid (FFA)

For the Free Fatty Acid (FFA), the analysis was done by titrating the mixture of the sample with 0.1N potassium hydroxide (KOH). The titration for each sample was immediately stopped until colour change of the sample mixture from yellow to reddish-pink was observed. The volume of 0.1N of KOH needed for the colour change to occur was recorded and tabulated in Table 3. Next, the FFA content percentage based on palmitic acid was calculated by using the data from Table 3 and being presented in Graph 2.

From the observation of Graph 2, it can be seen that the condition for the oil sample to have a high content of FFA which is of value 0.4608 is at ratio 1:0.5 of operation power of 600W. Meanwhile, for the least FFA content percentage in the oil sample which is of value 0.2278 is at condition of ratio 1:1 at power 800W. Since low FFA is preferable for food grade oil production as mentioned by Tagoe[2] in his writing, it can be deduce that the conditions of operation that produces an average of high fatty acid amount, in this case is the ratio of 1:0 and 1:0.5 will not be suggested or proposed for an industrial-scale oil production. The idea of improving the oil quality production may be referred by considering this data for future palm oil production reference.

Table 3: Volume of KOH needed for the colour change to occur by respective sample

Label	Ratio	Power (W)	Volume of KOH needed for the colour change to occur (mL)
1	1:0	600	25.9
2			30.0
3		800	30.2
4			26.7
5		1000	28.9
6			26.2
7	1:0.5	600	36.0
8			29.9
9		800	25.1
10			27.8
11		1000	29.9
12			23.0
13	1:1	600	28.2
14			26.3
15		800	32.0
16			17.8
17		1000	24.4
18			28.8

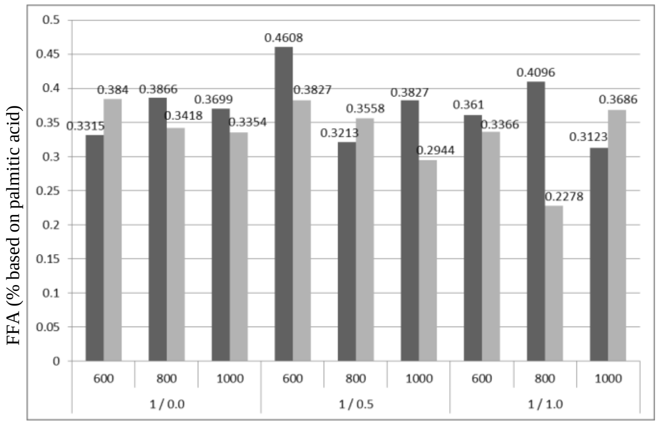


Fig. 3: Graph of FFA content percentage based on palmitic acid of all samples.

As a result, it can be said that the microwave sterilization pre-treatment method with condition of ration 1:1 of high operating power is suggested to be an effective process of enhancing oil yield and quality due to its low FFA content. This statement is supported by I.Umudee[5] in his journal of sterilizing oil palm fresh fruit using microwave technique. In the journal, he mentioned that reducing the increasing rate of FFA is needed for better oil quality production. Thus, it can be said that the study of this research contributed to the effort of producing better quality of palm oil.

IV. Conclusion

Microwave sterilization is an alternative method of pre-treatment of palm fruits oil extraction process besides other conventional method such as cracking. Eventhough this method is proved to be a clean method as mentioned by S.F. Cheng [3] in his study, the conditions of this sterilization pre-treatment moreover gives direct impact on the quality of the crude palm oil being produced in the process.

This study of microwave sterilization pre-treatment yield a product of oil extract yield, FFA characterization and its content compositions; segregated either high or low composition amount. The fractions indeed affect the acidity of the product and its yield production, indicating its quality and worth.

The study deduces that low FFA content is a preferable oil extract for it contains good quality product and do not be the aspect of consideration in further process utilization; as obtained in this experimental study which is of value of 0.2278 and oil yield of 0.6263 in fraction. These preferable results may be achieved through experimenting on the parameter change on the microwave sterilization pre-treatment conditions. All in all, for this particular case of the study, increasing operating power and ratio may bear a worthy oil products.

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