Microwave Sterilization of Oil Palm Fruits: Effect of Power, Temperature and *D*-value on Oil Quality

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***Abstract*—Microwave sterilization of oil palm fruits offer significant advantages in fast process due decimal reduction time (*D*-values) for this typical process was less than 17 minutes. It also required lower energy to increase temperature of the fruits during sterilization process. Instead of better operation process, palm oil quality is significant to investigate so as to evaluate relationship between process parameters (*D*-value, temperature and power) and oil quality. Free fatty acid (FFA) of palm oil was observed below standard requirement for commercial palm oil. Other minor component such as vitamin E was found on significant concentration in palm oil, while carotenoids content was lower than carotenoids in commercial palm oil. Reducing *D*-value at elevated power and temperature has improved reduced sterilization period and protect oil quality from lipases activity. As opposite, those elevated temperature promoted degradation of carotenoids in palm oil. However it did not inffluence the quality of vitamin E in palm oil.**

***Index Terms*—free fatty acid (FFA), sterilization process, lipase activity, carotenoids.**

I. Introduction

Sterilization on palm oil milling is purposes to protect oil quality by inactivate lipase on producing free fatty acid (FFA). Industrial oil palm sterilization is mainly steam batch process which is carried out with 3 kg/cm^2 in pressure and temperature of 140^{o}C [1] for about 80-90 minutes [2]. Due to the demand of palm oil increasing, effective sterilization process is needed especially for better process. Sterilization of oil palm fruits by microwave irradiation offer significant improvement in term of fast sterilization process as to inactivate lipase and relatively low temperature of operation [3]-[6]. *D*-value for such sterilization is reported less than 17 minutes utilizing power density of 1199.63 W/kg and 239.51 W/kg respectively [7]. Meanwhile performace of sterilization process not only depend on how fast process has acomplished and how less energy is required, but also include quality of palm oil product. This study discussed the quality of palm oil and their relationship with power density and *D*-value. Quality to be discussed are include FFA, carotenoids, and vitamin E in palm oil.

II. Materials and Methods

A. Materials

The materials used for the study include oil palm fresh fruit bunch (FFB) (*Tenera* variety) obtained from Universiti Teknologi Malaysia Plantation, microwave oven (Sharp Model: R-958A), data logger (Pico Temperature Data Logger, PT 104), and hydraulic presser (fabricated). The microwave oven was connected with data logger and computer to monitor and record the temperature of oil palm FFB during sterilization process.

B. Methods

Microwave sterilization process: Sample preparation was cutting oil palm FFB using chain saw (Tokai 3600) into 0.5, 1.0 and 1.5 kg respectively and placed in a dry environment before sterilization. To start the sterilization, sample was placed in the centre of the microwave and exposed to microwave irradiation at high, medium high and medium power level and the temperature changes was monitored, measured and recorded for every 4, 7, 10, 13 and 16 minutes intervals using thermocouple type J which was punched into the oil palm fruit at three point. The sterilization was carried out in triplicates. After the sterilization, the fruits was pressed using hydraulic presser to squezee the oil.

FFA test: It was conducted according to MPOB test method. It used neutralized 2-propanol in amount of 50 ml to neutralize 0.5-2.0 g of palm oil sample. After regulating the temperature to 40^{o}C, the sample was titrated against standard NaOH (0.1M) using phenolphthalein 1% as indicator to first permanent pink [8], [9]. FFA concentration is calculated by multifying

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volume of NaOH with its concentration divided by number of sample.

Carotenoids test: The carotenoids was determined using spectrophotometer according to MPOB Test Method [8]. The measurement is taken at 446 nm of the absorbency of a homogenized and diluted sample, using 1 cm quartz cuvettes. The n-hexane was used as the reagent to dilute the oil samples. The color of the diluted oil is brighter so that the absorbance at 446 nm is within Beer's Law [10]. The carotenoids content was then calculated using the calibration curve, which was obtained using known concentration of β-carotene [11].

Vitamin E test: A known amount of palm oil was weight and dissolved with hexane in a 1.0ml vial. The prepared oil sample was then injected into a Agilent HPLC 1100 series equipped with flurosence detector. A SI- 60 column was used with mobile phase of hexane: tetrahydrofuran: isopropanol (1000:60:4 v/v/v) at a flowrate of 1.0 ml min^{-1}. A standard sample with tocotrierols was also prepared using the same method [12].

III. Results and Discussion

A. Power, Temperature, and D-value Relationship

In oil palm sterilization, time of exposure is refered to *D*-value which is time needed to reduce 90% activity of lipases. [13], [14]. Microwave sterilization of oil palm fruits is actually a destruction process of lipases by first order kinetic reaction [7]. Lipases or triacylglycerol acylhydrolases, EC 3.1.1.3 in oil palm fruit is defined in the oil fraction of mesocarp [15]. Nature lipolytic activity by lipases at lipid-water interface in the mesocarp results FFA which is unaccepted at certain level [16].

Microwave power, temperature and *D*-value from this study are shown in Table I. Power and *D*-value relationship is known as microwave intensity of sterilization process. Destruction process of lipases by microwave irradiation required power so as to increase temperature of fruits, and provided energy to start destruction process (activation energy, E_a). More power is required to increase temperature and E_a, and to obtain faster destruction process (*D*-value is short). Sterilization of small size oil palm fruits sample proceed faster as to compare to big size samples. Power evaluation observed higher fruit's temperature obtained when sterilized small sample. Sterilization of 0.5 kg sample using power of 599.82 W for example was faster as to compare to sterilization of 1.0 and 1.5 kg sample using the same magnitude of power. *D*-value and temperature of 0.5 kg sample was 8.33 minutes and 82.0^{o}C respectively, while 1.0 and 1.5 kg sample needed 12.35 and 14.09 minutes to increase temperature up to 80.0^{o}C and 76.5^{o}C respectively using the same microwave power (599.82 W). Relationship between temperature, *D*-value, and E_a expressed in first-order kinetics and Arrhenius equations [13], [14], [17].

In most microwave study, power and material always represent by power density which expressed number of power apply to the oil palm fruits sample per kg. High power density expressed effectiveness of microwave sterilization process due to maximum microwave energy being absorbed by small sample. This increased temperature and E_a, and fast destruction process obtained. Relationship between power density and *D*-value shown in Fig. 1.

TABLE I. Power and D-value

Oil palm fruits sample (kg)	Microwave power (W)	Temperature (ºC)	*D*-value (minutes)
0.5	359.27	70.50	12.66
	427.29	80.46	9.71
	599.82	82.00	8.33
1.0	359.27	75.00	14.29
	427.29	78.00	12.82
	599.82	80.00	12.35
1.5	359.27	70.00	16.95
	427.29	75.00	14.29
	599.82	76.50	14.09

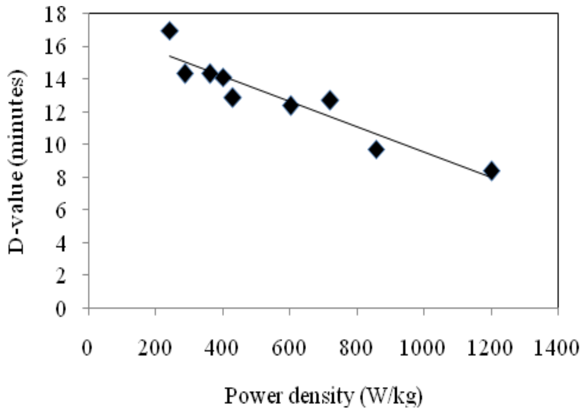

Figure 1. Relationship between power density and *D*-value.

B. Effect of Power, Temperature and D-Value on Palm Oil Quality

Three major simultaneous process occurs during sterilization process include electromagnetic irradiation, heat transfer, and destruction process. Mass transfer is actually present by water evaporation, but considered insignificant due to short *D*-value aplication [18]-[24]. During irradiation period, re-orientation of water molecules within mesocarp generated heat, which transfered into abscission layer-air interface. This phenomena elevated surrounding temperature that inactivated the lipases activity and promoted degradation of nutrients. Instead of FFA, high temperature and longer heating period are not considered in application. Both factors yielded low content of carotenoids. Similar resulted reported contribution of both temperature and heating time in nutrients degradation of fruits [25] include oil palm fruits [26], [27]. Quality of palm oil from the microwave sterilization shown in Fig. 2 and Fig. 3.

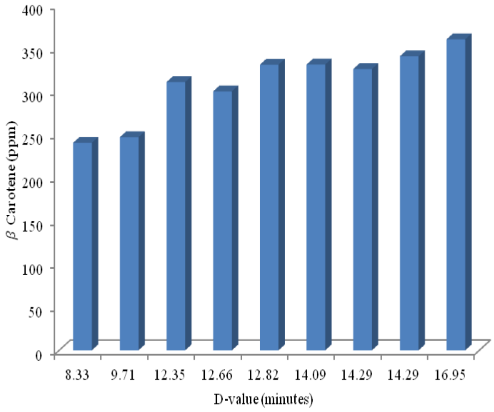

Figure 2. Concentration of carotenoids as β carotene in palm oil after microwave sterilization.

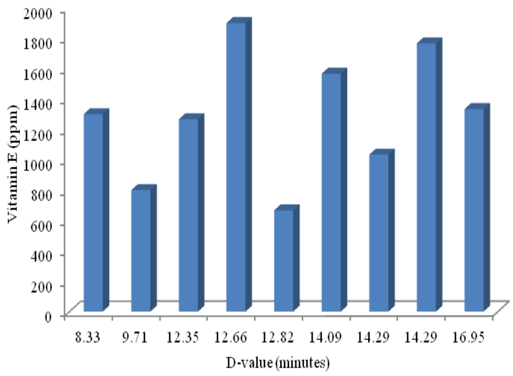

Figure 3. Concentration of vitamin E in palm oil after microwave sterilization

Measurement of FFA as key parameter of palm oil quality showed inconsistent results actually, which is insignificant, because FFA concentration measured below maximum standard of FFA requirement for commercial palm oil (maximum FFA concentration of commercial palm oil is 3.50%). FFA level of concentration observed between 0.30% to 1.39% (FFA average is about 0.70%). This FFA results expressed process performance in destruct or inactivate the lipases activity in the fruits during microwave irradiation. High temperature and longer heating time period usually obtained low level of FFA concentration as major activity by lipases being inactivated.

Carotenoids content in palm oil is mainly found between 700-800 parts per million (ppm) as β-carotene [15]. This study observed carotenoids content in palm oil from microwave sterilization process was below 400 ppm for all level of *D*-value. Lower carotenoids content indicated degradation of carotenoids by microwave irradiation during sterilization of oil palm fruits. Significant decrease of β-carotene was observed at both elevated temperature and *D*-value. Fig. 2 shows tendency of high β-carotene content (300.16–360.40 ppm) if oil palm fruits sterilized more than 9.71 minutes. For those sterilization process (*D*-value is 12.35 minutes above), requirement of power was relatively lower (359.27 W) and/or low power density, as the results using relatively big size sample (1.0 kg and 1.5kg). Similar results also reported by other researchers using different method [26].

Vitamin E in palm oil comprises of tocotrienols (78-82%) and tocopherols (18-22%). The vitamin E content in crude palm oil ranges between 600 – 1000 ppm [15]. This study observed significant amount of vitamin E that still present in palm oil after oil palm fruits irradiated by microwave energy. This findings expressed relative stability of vitamin E on temperature and time of exposure. As shown in Fig. 3, the vitamin E content of palm oil obtained from fast sterilization process (*D*-value is 8.33 minutes) and slow sterilization process (*D*-value is 16.95 minutes) were 1300.00 ppm and 1333.33 ppm respectively.

IV. Conclussion

Sterilization of oil palm fruits by microwave irradiation can be proceed less than 17 minutes with relatively lower energy support to increase fruit's temperature. However investigation of palm oil quality is significant, so as evaluation towards process parameters (*D*-value, temperature and power), and their relationship with oil quality. FFAs concentration observed in this study were below standard requirement for commercial palm oil, so as vitamin E which found in palm oil with significant concentration. Other palm oil compenent is carotenoids which found less than carotenoids from commercial palm oil due to degradation of carotenoids was promoted by elevated temperature. Meanwhile it did not inffluence the quality of vitamin E in palm oil, and proved succesfully facilitated inactivation of lipases.

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