Sterilization of Oil Palm Fruit Using Radio-Frequency Heating

Attapon Choto, Chakrit Thongurai, Nattawan Kladkaew and Montep Kiatweerasakul

***Abstract*—**The objective of this research is to study on the sterilization of oil palm fruits by radio-frequency (RF) heating in term of enzymatic inactivation. Oil palm fruits were heated by the RF applicator at different frequency, and periods of heating also be varied. The experimental results revealed that the increase in RF frequency and duration of heating causes the increasing of mesocarp temperature. From experimental results, it showed that the optimum condition of RF heating in order of interrupting the enzymatic reaction was at 27.12 MHz and 6 minutes of operating, which can increase the mesocarp temperature to 329.5 K. The obtained energy efficiency at this condition was 19.12 %. The tested oil palm fruits can be stored for 4 days in ambient condition with the increase of free fatty acid is acceptable. On the basis of experimental results, it can be showed that RF could inhibit the increasing of free fatty acid in oil palm fruits, however this process should be studied further.

***Keywords*—**Sterilization, Palm fruit, Radio-frequency, Free Fatty Acid.

I. Introduction

HIGH content of free fatty acid (FFA) in crude palm oil is the most problems for the palm oil mill. After harvesting, oil palm delivered to mill early before the high rate increasing of FFA will be occurred.

Sterilization is a step in the milling process, which objects to inactivate the naturally occurring enzymes in the palm fruits which split the oil to FFA and encourage remove the fruit from the bunch [1]. Conventional sterilization of oil palm in the palm oil mill is wet process which uses steam and hot water. The oil palms are subjected to high pressure at 15-45 psi for 90 minutes and the temperature more than 100°C [2], [3]. However, steam sterilization process has produced much waste water. Thus the high cost of water treatment was imperative to rigorous environmental standard. The milling process always practiced stringent control on the process in order to produce crude palm oil (CPO) with acceptable specifications, especially on parameter such as moisture and FFA content. High FFA content is inevitable since wet processes are engaged and the presence of water will promote hydrolysis of oil to FFA [4]

RF is a new tool for high temperature process which is rapid and uniform heating including decrease sintering temperature. RF is a range within electromagnetic spectrum which covers a frequency between 1 to 300 MHz. Microwave are similar to RF in their heating behavior but it has a higher frequency range [5]. In addition, the difference between RF and microwave is principally of technology. In RF, the product to be heated is placed between the electrodes plates while in microwave, heating occurs within metal chamber such as microwave oven [6].

In an RF heating process, the RF generator produce an electric field between electrodes where the alternating energy causes polarization, and where the molecules in the product continuously reorient themselves to face opposite poles [7]. When an alternating electric field is applied to material, it causes movement of positive ions in the material towards negative regions of electric field and the movement of negative ions towards positive regions of electric field [8]. The movement of ions in this characteristic is referred to as ionic depolarization and is principally resistance heating as found in OH. Heating occurs due to electric field is not static, with polarity continually changing at high frequencies (e.q. 13.56, 27.12 and 40.68 MHz for RF). However, irregardless of the frequency, the continued alternated of polarity in the electrical field leads to the oscillation of ions forwards and backwards in the product with the effect of this being the internal generation of heat within the product by friction of dipolar molecules such as water in a product [8], [9].

The aim of this research was to monitoring the feasibility of the beneficence of RF heating as a primary stage of the small milling process for enzymatic denatured which could be reduce increasing rate of FFA, extensively store will not be problem of milling process.

II. Experimental Procedure

A. Materials

The oil palm fruits were collected from Songkla and nearby. The experiments conducted within 24 hrs after harvested. The

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experiments were carried out on 150 g of fruitlets which is detached by slight push of the finger from the bunch.

B. Radio-Frequency heating

The heating process was carried out by using a RF application unit. It consists of RF generator and RF applicator which matching network and parallel plate electrodes are the major parts of it. The dimension of parallel plate are 16x28 cm^2.The distance from the bottom to the top electrode was 4 cm. The RF generator has operating frequency of 13.56 and 27.12 MHz respectively.

The oil palm fruits were placed between two plate electrodes, then heated by RF unit at 500 watt for 3, 6, 9 and 12 minutes respectively. The temperature and temperature distribution were measured before and after heating by using infrared camera (Model FLIR i3, FLIR Systems, Inc.)

The energy efficiency of RF used in the study was also investigated by comparing the energy provided of RF and following equation:

$$Q_{generated} = P \times t \qquad (1)$$

Where $Q_{generated}$ is energy generated (kJ), P is transmission power (W) and t is retention time (s).

$$Q_{total} = Q_{fiber} + Q_{palm\ \ oil} + Q_{water} + Q_{vaporization} \qquad (2)$$

Where Q_{total} is total energy absorbed (kJ),Q_{fiber} is energy absorbed of fiber in palm fruit, $Q_{palm\ oil}$ is energy absorbed of palm oil (kJ), Q_{water} is energy absorbed Of water in palm fruit (kJ) and $Q_{vaporization}$ is energy of vaporization of water in palm fruit (kJ).

$$efficiency(\%) = \frac{Q_{total}}{Q_{generated}} \times 100\% \qquad (3)$$

C. Free Fatty Acid Content of Palm Oil Analysis

The FFA content of extracting oil palm was analyzed according to AOCS Official Method Ca 5a-40 [10].

III. RESULTS AND DISCUSSION

A. Temperature Distribution

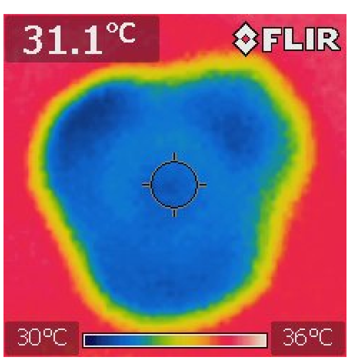
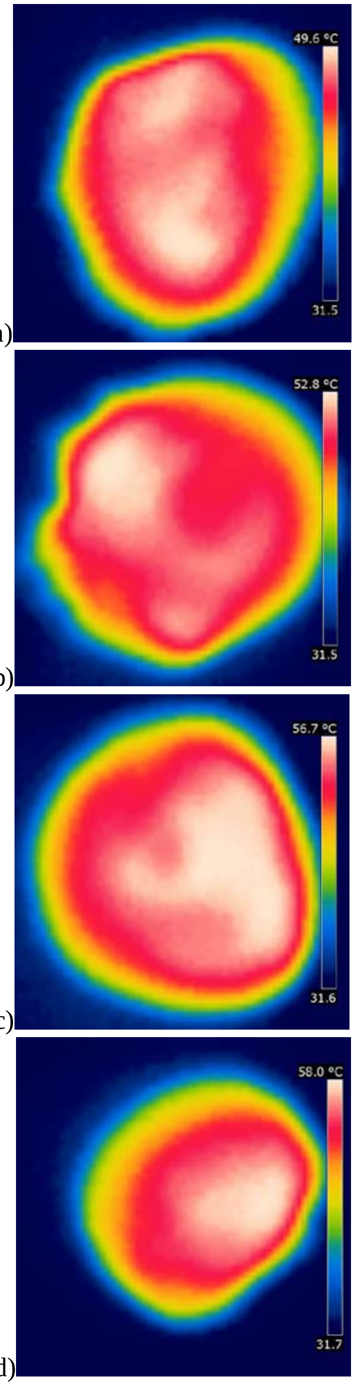


Fig.1. Temperature distribution within oil palm fruits prior to RF heating.

Fig.1. presents the typical internal temperature distribution of oil palm fruits before to heated by RF. The red background of thermal images represents temperature of surroundings, and the blue side demonstrates temperature distribution of oil palm fruits.



(a) (b) (c) (d)

Fig.2. Temperature distribution within oil palm fruits after RF heating at 13.56 MHz. The heating time were (a) 3 minute (b) 6 minute (c) 9 minute and (d) 12 minute respectively

The temperature distribution within oil palm fruits after RF heating at 13.56 and 27.12 MHz are presented in Figs.2-3, respectively. The blue background of thermal images represents temperature of surroundings. A transition from green to pink rings showed that oil palm fruits had a higher internal temperature than at surface due to convective heat transfer between the oil palm fruits and surrounding. Heat conduction within oil palm fruits, resulting from a higher surface temperature next to the surroundings, would generate a temperature gradient inside an oil palm fruits.

(a) (b) (c) (d)

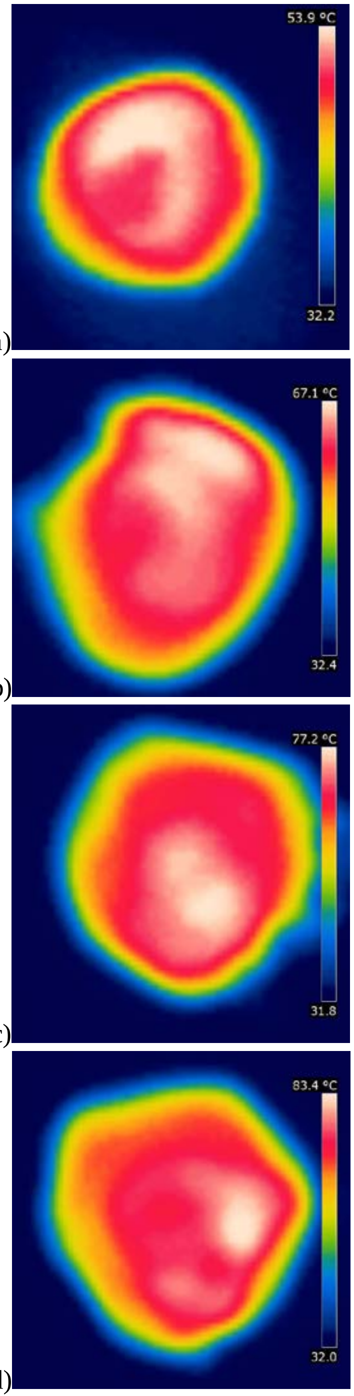


Fig.2. Temperature distribution within oil palm fruits after RF heating at 27.12 MHz. The heating time were (a) 3 minute (b) 6 minute (c) 9 minute and (d) 12 minute respectively

B. Sterilization of Oil Palm Fruilet

The mesocarp temperature of RF heating oil palm fruit was showed in Table I, the result indicated that mesocarp temperature of palm fruits increases correspondingly as frequency and retention time. The maximum temperature reaches 336.6 K by using 27.12 MHz within 12 minutes.

TABLE I
EFFECT OF RF HEATING FREQUENCY AND TIME ON MESOCARP TEMPERATURE OF OIL PALM FRUIT AT 500 WATT

Retention time (min)	Temperature of mesocarp (K)	
	13.56 MHz	27.12 MHz
3	316.9	320.5
6	319.9	329.5
9	325.3	335.5
12	330.0	336.6

Fig.4. shows the percentage increments of FFA of oil palm fruit that carried out by 13.56 MHz, 500 Watt RF-heated oil palm fruit compared between heating and non-heating. The results shown that increments rate of FFA of oil palm heated by RF lower than non-heating oil palm fruits. However, consider on the percentage increment of FFA to be hardly different between non-heating and heating for temperature at 316.9 K .Therefore temperature lower than 316.9 K cannot halted enzymatic reaction.

Fig.5. present the percentage increments of FFA of oil palm fruit that carried out by 27.12 MHz, 500 Watt RF-heated oil palm fruit. The results indicated that temperature higher than 320.5 K can reduce increment rate of FFA. The increasing of FFA in heated oil palm fruits above 335.5 K rarely increase when compared with non-heating oil palm fruits.

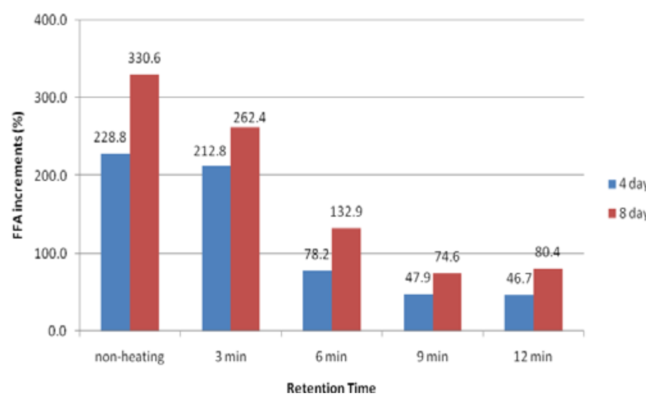


Fig.4.The percentage increments of FFA content at 13.56 MHz RF-heated of oil palm fruitlet.

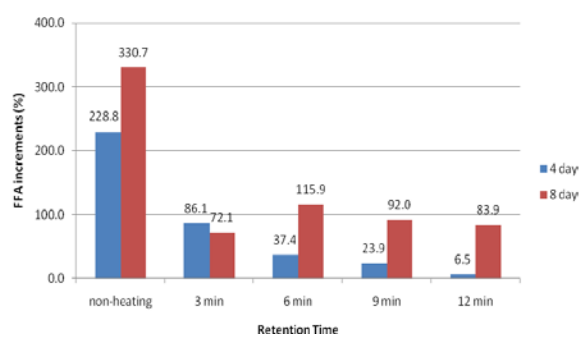


Fig.5.The percentage increments of FFA content at 27.12 MHz RF-heated of oil palm fruitlet.

As a result of FFA data mentioned above, RF sterilization system can be halted enzymatic reaction. It could be retained oil palm fruit until 4 day, advantages for pressing tarried oil palm fruit.

TABLE II
THE EFFICIENCY OF RF HEATING ON PALM FRUITS AT 500WATT

	Retention Time (min)							
	13.56 MHz				27.12 MHz			
	3	6	9	12	3	6	9	12
Energy absorbed of fiber (kJ)	0.92	1.48	1.91	2.473	1.48	2.37	3.07	3.16
Energy absorbed of palm oil (kJ)	1.05	1.67	2.17	2.808	1.68	2.70	3.48	3.58
Energy absorbed Of water in palm fruit (kJ)	15.87	15.87	15.87	15.871	15.87	15.87	15.87	15.87
Energy of vaporization of water in palm fruit (kJ)	8.95	13.47	18.33	26.418	8.95	13.47	18.33	26.42
Total energy absorbed (kJ)	26.80	32.49	38.28	47.57	27.98	34.41	40.75	49.03
Energy generated (kJ)	90.00	180.00	270.00	360.00	90.00	180.00	270.00	360.00
Efficiency (%)	29.78	18.05	14.18	13.21	31.09	19.12	15.09	13.62

C. Energy efficiency of RF sterilization

RF heating of oil palm fruits, energy efficiency was generated by the transmission power of the RF and absorbed by oil palm fruits. Table II presents the energy data calculated in experimental.

The results shown that value of energy efficiency decrease as the RF exposure duration increase. The efficiency of RF for 13.56 and 27.12 MHz at duration time 3, 6, 9 and 12 minutes shown in Table II.

IV. CONCLUSION

The present study shows that oil palm fruits can be stabilized by heating oil palm with RF to inactivate enzymatic reaction. In this study, the optimal condition of RF heating in order of interrupting the enzymatic reaction was at 27.12 MHz and 6 minutes. The tested oil palm fruits can be stored for 4 days in ambient condition with the increase of free fatty acid is acceptable. The obtained energy efficiency of RF at this condition was 19.12 %. On the basis of experimental results, it can be showed that RF heating could inhibit the increasing of FFA in oil palm fruits, however this process should be studied further.

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