



CAROTENOIDS PRESERVATION DURING STERILIZATION OF PALM FRUIT USING MICROWAVE IRRADIATION

Maya Sarah

Department of Chemical Engineering, Universitas Sumatera Utara, Padang Bulan, Medan, Indonesia

E-Mail: mayasharid@yahoo.com

ABSTRACT

Carotenoids are one among valuable nutrients in oil palm fruit. The facts carotenoids are vulnerable to heat were indicated by lower carotenoids concentration in palm oil after sterilization process. Sterilization of oil palm usually conducted at temperature above 150°C at which carotenoids degraded from 4000 ppm to 700 ppm. To retain carotenoids, sterilization of oil palm fruit should be conducted at low temperature. Microwave irradiation offers flexibility in arranging heat level and irradiation time for sterilization process as compared to thermal sterilization. This study aims to evaluate combination of time and temperature for microwave sterilization and develop safety margin that deactivate lipase and at the same time retain carotenoids. To determine safety margin for carotenoids content, an analysis on relationship between *D*-value and temperature was conducted for lipase inactivation process and carotenoids degradation. The *D*-values of lipase were determined from lipase inactivation at various power levels, sample's size of oil palm fruit and irradiation time. Microwave oven that connected with thermocouple, data logger and computer was used to determine *D*-value. The safety margin for this process was developed from *D*-value curve of both lipase and carotenoids. Areas under intersection between two curves represent combination of time and temperature for irradiation process. This time and temperature combination at the intersection points offering maximum and minimum level of carotenoids content in palm oil product. It was concluded that sterilization of oil palm fruits by microwave irradiation may occur at low temperature (below 60°C) and require longer irradiation time (more than 20 min). This microwave sterilization process can deactivate lipase and also retain carotenoids in palm oil.

Keywords: carotenoids, sterilization, microwave irradiation.

INTRODUCTION

Carotenoids responsible for palm oil stability and nutritional value (Melendez-Martinez, 2007). Structure of carotenoids with conjugated double bonds makes its vulnerable to heat. Heating of oil palm fruit at temperature of 60°C above accelerates degradation of carotenoids which occurred slowly at ambient temperature. Conventional sterilization in palm oil milling that carries out at temperature above 150°C degrades carotenoids concentration in oil palm fruit from 4000 ppm to 700 ppm (Sambanthamurthi *et al.*, 2000). Palm oil obtained from extraction of this sterilized fruit is Red Palm Oil (RPO). RPO consist of carotenoids that mainly found between 700-800 ppm as β -carotene (Sambanthamurthi *et al.*, 2000). Carotenoids that contribute to yellow to red-orange color will be totally removed from the oil during refining process to produce palm oil. This removal of organic pigment is due to consumer's preferences.

In fact, RPO with high carotenoids content have many advantages. Carotenoids are sources of vitamin A precursors and act as antioxidants that protect human living cells from free radicals. Masni *et al.* (2013) reported oil palm fruit having potency as sources of carotenoids because their absorbency level is higher (around 98%), as compared to other sources (37-75%). Absorption rate of RPO carotenoids is 15 to 40 times greater as compared with existing carotenoids in carrots. The high level is due to the absorption of carotenoids RPO are in the oil medium. The fact RPO rich in carotenes and high level absorbency makes RPO potentially used to combat vitamin A deficiency (Masni, 2013).

Sterilization of oil palm fruit can be carried out with microwave irradiation. Several studies reported heating and sterilization of oil palm fruit by microwave irradiation (Tan, 1981, Chow and Ma, 2007, Sukaribin and Khalid, 2009, Cheng *et al.*, 2011, Sarah and Taib, 2013b, Sarah and Taib, 2013a, Umudee, 2013). This method may reduce sterilization time and temperature. The purpose of microwave sterilization is to inactivate lipase and soften the fruits. Sarah and Taib (2013) reported *D*-value of lipase from microwave sterilization of oil palm fruit (Table-1) that range between 8.3 min ($T=68^{\circ}\text{C}$) to 16.9 min ($T=82^{\circ}\text{C}$) (Sarah and Taib, 2013). To retain carotenoids, sterilization of oil palm fruit should be conducted at low temperature. This is possible due to lipase deactivation occur at temperature above 47°C (Ebongue *et al.*, 2006), while carotenoids degradation starts at temperature of 60°C. Fratianni *et al.* (2010) reported *D*-value and temperature of carotene degradation (Table-1) (Fratianni *et al.*, 2010). This kinetic data were obtained from orange juice. Both *D*-value lipase and carotenoids indicate flexibility of microwave irradiation in arranging heat level and irradiation time for sterilization process as compared to thermal sterilization. *D*-value may define as the heating time to eliminate activity of enzyme or nutrient, by a factor of 10 at certain temperature (Smith, 1990, Neef *et al.*, 2002, Karel and Lund D., 2003, Awuah *et al.*, 2007). *D*-z Method that derived from thermal sterilization can be used to evaluate *D*-value based on kinetic data of enzyme inactivation or nutrient degradation.



METHODS

Potency of microwave sterilization to retain carotenoids content in palm oil was evaluated by combining *D*-value curve of both lipase and carotenoids. This method was adopted from Goff (2004). *D*-value curve of lipase was determined by Thermal Death Time (TDT) method, while *D*-value curve of carotenoids was determined by Thermal Resistance method (Karel and Lund, 2003). This study utilizes data reported by authors that had been published early (Sarah and Taib, 2013a, Sarah and Taib, 2013b) and Fratianni *et al.* (2010) to predict various combinations of *D*-value and temperature by using simple regression line method. Each *D*-value was obtained from survivor curves of lipase and carotenoids. Determination of *D*-value of lipase had been reported by same author elsewhere (Sarah and Taib, 2013a, Sarah and Taib, 2013b). Meanwhile, determination of *D*-value of carotenoids had been reported by Fratianni *et al.* elsewhere (Fratianni *et al.*, 2010). Each pairs of data were used to

construct *D*-value curve and determined safety margin. Total area under *D*-value curve of carotenoids and above *D*-value curve of lipase represent combination of *D*-value and temperature that can be used to sterilize oil palm fruit by microwave irradiation. Boundary of this area is safety margin operation for microwave sterilization of oil palm fruits that may be used to produce RPO with high carotenoids content.

RESULTS AND DISCUSSIONS

Figure-1 shows relationship between *D*-value with temperature for lipase inactivation and degradation of carotenoids. Relationship between *D*-value and temperature for lipase inactivation were constructed as regression line based on data as depicted in Table-1. Similar method is used for carotenoids degradation. The regression line and coefficient determination of Figure-1 is shown in Table-2.

Table-1. *D*-value and temperature of lipase and carotenoids.

Parameters	Material	<i>D</i> -value (min)	Temperature (°C)	z-value (°C)
Lipase*	Oil Palm Fruit	8.3	82	26.8
		9.7	81	26.8
		12.3	80	22.5
		12.6	71	26.8
		12.8	78	22.5
		14.2	75	21.8
		16.9	70	21.8
α -Carotene**	Orange juice	99.3	60	12.9
		29.8	70	12.9
		5.9	75	12.9
β -Carotene**	Orange juice	99.7	99.7	10.9
		24.6	24.6	10.9
		3.5	3.5	10.9
Total Carotenoids**	Orange juice	56.6	60	14.2
		16.5	70	14.2
		4.5	75	14.2

Sources: *Sarah and Taib (2013b) and **Fratianni et al. (2010)

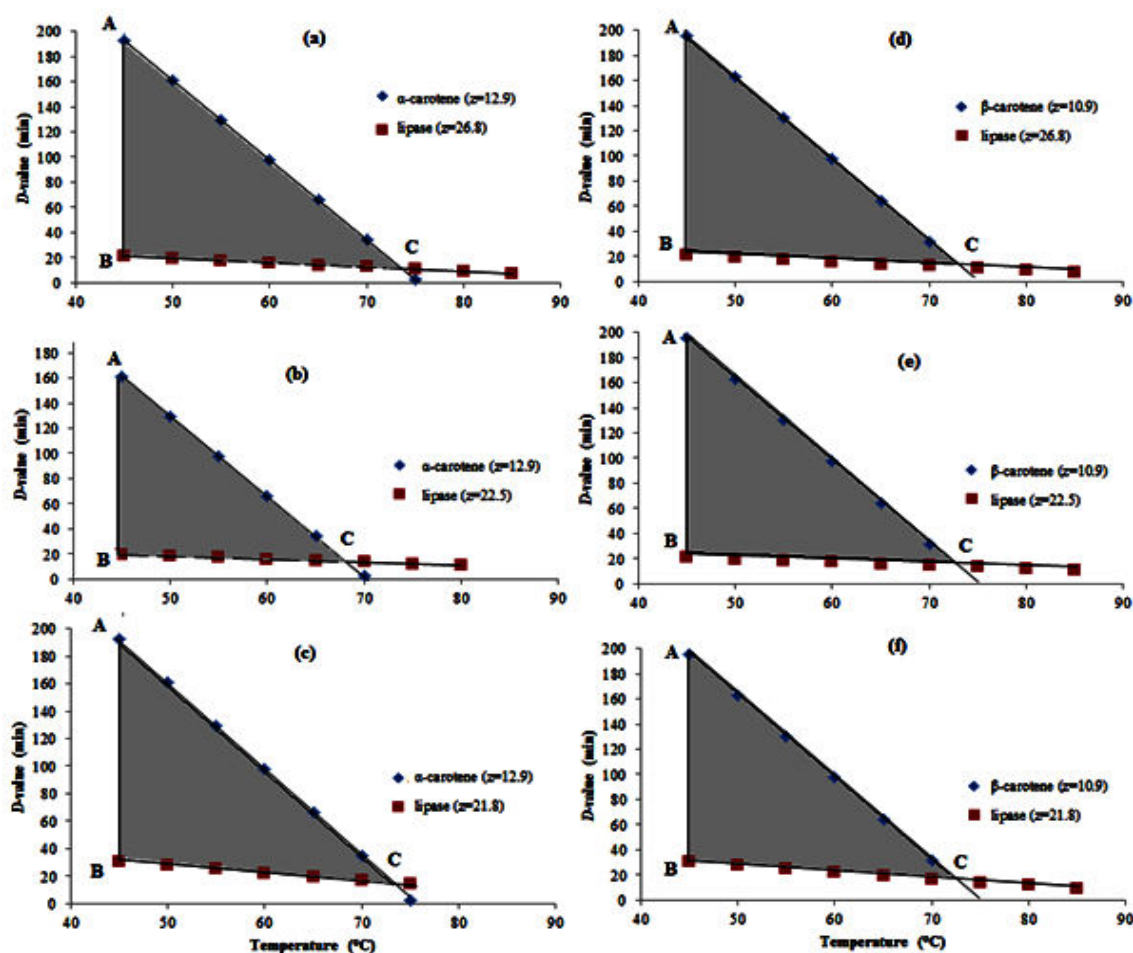
**Table-2.** Regression line to construct safety margin of carotenoids.

Components	Regression line	R ²
Lipase (z=26.8)	$y = -0.35x + 37.5$	0.9423
Lipase (z=22.5)	$y = -0.25x + 32.3$	1.0000
Lipase (z=21.8)	$y = -0.54x + 54.7$	1.0000
α -carotene (z=12.9)	$y = -6.33x + 477.6$	0.9929
β -carotene (z=10.9)	$y = -6.57x + 491.6$	0.9849
Total carotenoids (z=14.2)	$y = -3.55x + 268.5$	0.9876

Safety margin for α -carotene and β -carotene

Lipase and carotenoids will be destroyed if sterilization carries out with any combination of *D*-value and temperature at the top and right of each line, whereas below and to the left of each line, the lipase and carotenoids will not be destroyed. The shaded area represents the combination of temperature and *D*-value,

where lipase can be inactivated while carotenoids can be retained. Figure-1(a)(b)(c) show safety margin from the microwave sterilization to retain α -carotene content in palm oil at various *z*-value of lipase, while Figure-1(d)(e)(f) show safety margin to retain β -carotene. The *z*-value was obtained from *D*-value curve at various microwave

**Figure-1.** Safety margin for microwave sterilization to retain carotenoids in palm oil based on data reported by Sarah and Taib (2013a and 2013b) and Fratianniet al. (2010).

There are 3 critical situations to be considered that represent by points A, B and C in the safety margin area. Each shows 3 type conclusions that can be drawn

related to the choice of temperature and time for microwave sterilization, with assumption the kinetic of carotene degradation in palm oil and orange juice is not



significance different. Temperature and D -value at critical point are listed in Table-3. arrangement for microwave sterilization of oil palm fruit

Table-3. Critical temperature and D -value in safety margin for microwave sterilization of oil palm fruit.

z -value ($^{\circ}\text{C}$)				Safety margins critical points					
Lipase	α -carotene	β -carotene	Total carotenoids	A		B		C	
				T ($^{\circ}\text{C}$)	D -value (min)	T ($^{\circ}\text{C}$)	D -value (min)	T ($^{\circ}\text{C}$)	D -value (min)
26.8	12.9	-	-	45	192.7	45	21.4	75	17
22.5	12.9	-	-	45	161	45	19.8	70	19
21.8	12.9	-	-	45	192	45	30.4	78	18
26.8	-	10.9	-	45	195.9	45	21.3	73	19
22.5	-	10.9	-	45	196	45	20	72	19
21.8	-	10.9	-	45	196	45	30.4	72	18
26.8	-	-	14.2	45	108.7	45	21.4	71	19
22.5	-	-	14.2	45	108	45	20	70	19
21.8	-	-	14.2	45	108.5	45	30	70	20

Critical point A represent microwave sterilization that can be carried out at low temperature but require long period of time. This microwave sterilization will inactivate lipase, but most of the carotenoids content is lost. This process is not recommended due to quality problem caused by prolonged heating in microwave sterilization. The fruits are too dry so it is difficult to extract the oil. Critical point B represents microwave sterilization that can be carried out at low temperature and short period of time. The sterilization may inactivate lipase and retain maximum carotene content in palm oil. This typical process is suitable for process that aims to retain carotene. Critical point C represents microwave sterilization that can be carried out at high temperature. Microwave sterilization will inactivate lipase and maintain minimum carotene in palm oil. This typical process is suitable for microwave sterilization that aims to yield palm oil with minimum carotene content. The fact that palm oil mill removes carotene from palm oil in deodorizing process added other advantage of this process as to facilitate deodorizing process.

To produce RPO, sterilization must be conducted using a pair combination of temperature and D -value at any point in the shaded area exclude critical points. Sterilization by microwave irradiation at temperature below critical point A and B will not obtain sterilize fruits or not deactivated lipase. Similar situation occurs if microwave sterilization is carried out for short period of time or less than 17 min (below critical point B). Prolonged heating above critical point A (more than 190 min) will obtain sterilize fruit, but most of carotene content is lost. Microwave sterilization of oil palm fruit that carry out at temperature above critical point C will obtain sterilize fruit but most of carotene content is lost. Fig. 1 shows β -carotene more sensitive on temperature as compare to α -carotene that indicated by z -value of β -

carotene lower than α -carotene. The z -value represents sensitivity of carotene due to temperature and D -value modification. Every increment temperature up to 10.9°C will reduces the D -value of β -carotene by a factor of 10, while to reduce D -value of α -carotene, temperature should be increased up to 12.9°C .

3.2 Safety margin for total carotenoids

Total carotenoids are expressed as a sum of single quantified carotenoids. Safety margin to maintain total carotenoids is shown in Figure-2. If we compare to Figure-1, sterilization time which indicated by D -value of lipase is similar with D -value lipase in Figure-1, but shaded area in safety margin to retain total carotenoids is smaller compare to typical shaded area in safety margin of β -carotene and α -carotene. Critical point to be considered in the border of safety margin in Figure-2 is indicated by point A, B and C. The critical temperature and D -value of total carotenoids in safety margin is shown in Table-3.

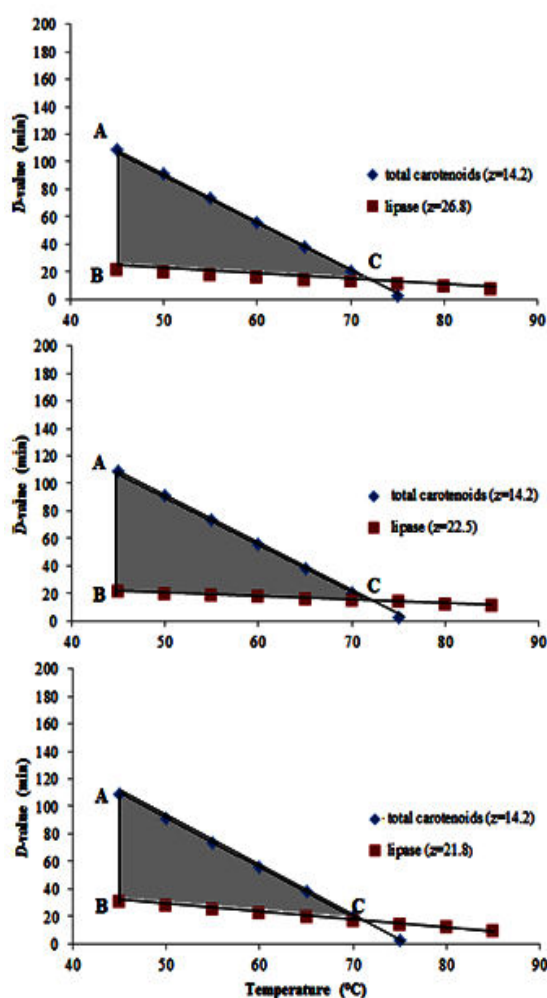


Figure-2. Safety margin for microwave sterilization to retain total carotenoids in palm oil based on data reported by Sarah and Taib (2013a and 2013b) and Fratianni *et al.* (2010).

To produce RPO with high total carotenoids content, sterilization must be conducted at temperature above critical point A and B ($T > 45^{\circ}\text{C}$) with D -value below critical point A (< 108 - 108.7 min). Prolonged heating with D -value above critical point A will destroy total carotenoids content. High temperature above critical point C (> 70 - 71°C) will also destroy total carotenoids.

Over all, this safety margin can be used to maintain all carotenoids in oil palm fruit include α -carotene and β -carotene because critical time which represent by D -value for total carotenoids (D -value < 108 - 108.7 min) is lower if we compare to α -carotene and β -carotene (D -value α -carotene < 192.7 min and D -value β -carotene < 196 min).

CONCLUSIONS

Microwave sterilization of oil palm fruit has the opportunity to be used to produce RPO. Safety margin to produce RPO had been constructed based on kinetic data of lipase and carotenoids (α -carotene and β -carotene and total carotenoids).

To obtain RPO, microwave sterilization should carry out using time and temperature combination in the shaded area below critical point A and above critical point B and C. To obtain optimum result, it is recommended to conduct further experiment to obtain kinetic data and D -value of carotenoids of oil palm fruit.

Overall, the best option to produce RPO is sterilization by microwave irradiation with short sterilization time. Normally this can be carried out at high temperature or high power level. In this study, combination of short sterilization time and high temperature are shown in Figures 1 and 2 around C inside the shaded area.

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