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BORANG PENGESAHAN STATUS TESIS♦

JUDUL: A NOVEL PROCESS FOR DEMULSIFICATION OF COCONUT OIL MILK EMULSIONS BY MICROWAVE RADIATION

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A NOVEL PROCESS FOR DEMULSIFICATION OF COCONUT OIL MILK EMULSIONS BY MICROWAVE RADIATION

NORLIA CHE SAAD

A thesis submitted in fulfillment
of the requirements for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical Engineering & Natural Resources

Universiti Malaysia Pahang

APRIL 2010

DECLARATION

I declare that this thesis entitled "A novel process for demulsification of coconut oil milk emulsions by microwave radiation'' is the result of my own research except as cited in references.The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………………………

Name of Candidate : Norlia Bt Che Saad

Date : April, 2010

Special Dedication of This Grateful Feeling to My…

Beloved mom and dad,
that always love me,
My friends that very supportive,
Lecturers and My Supervisor,
Assoc. Prof. Dr. Abdurahman Hamid Nour,
and all faculty members.

For all your care, support and believed in me.

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Abstract

The application of microwave radiation demulsification process in separation process has been increasingly important.There is several studies on demulsification using microwave radiation and the results are positive. This research aims to develop a generic but efficient and sustainable water/coconut oil separation method through process intensification and integration based on the application of microwave heating technology. This study is devided into two parts which are demulsification process and emulsion stability. The microwave is set at 720W for 5 minutes. Then the coconut milk is heated using microwave. After that the sample is taken out from microwave to 250ml measurement cylinder which is settling process is occured. The procedure mentioned above is repeated for the power 720W; 7 minutes, 540W; 5 minutes, 540W; 7 minutes. Each sample was run for 3 times per sample. Lastly the data is recorded.As a conclusion, the volume of water and oil separations for all samples were increased when the settling time was increased by increasing the power of microwave radiation. The microwave has high potential as a method to enhance the demulsification of coconut oil milk.

Abstrak

Aplikasi terhadap proses demulsifikasi ketuhar radiasi dalam proses pemisahan telah semakin penting. Beberapa kajian process demulsifikasi menggunakan radiasi gelombang mikro dan hasilnya positif. Penelitian ini bertujuan untuk membentuk air generik tapi efisien dan berterusan / kaedah pemisahan minyak kelapa melalui proses Intensifikasi dan integrasi berdasarkan pelaksanaan teknologi pemanasan ketuhar. Penelitian ini terbahagi kepada dua bahagian iaitu proses demulsifikasi dan kestabilan emulsi.Ketuhar ditetapkan pada 720W selama 5 minit. Kemudian santan dipanaskan dengan menggunakan ketuhar. Setelah itu sampel dikeluarkan dan dituangkan ke dalam 250 ml silinder untuk proses pemisahan. Prosedur tersebut diulang untuk 720W parameter; 7 minit, 540W, 5 minit, 540W; 7 minit. Setiap sampel dijalankan selama 3 kali. Data direkodkan.Kesimpulannya, ukuran pemisahan air dan minyak untuk semua sampel meningkat apabila masa pemisahan meningkat dengan meningkatkan kekuatan radiasi gelombang mikro. Ketuhar mempunyai potensi tinggi sebagai suatu kaedah untuk meningkatkan proses demulsifikasi terhadap santan kelapa.

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LIST OF SYMBOLS

w/o	- Water in oil
o/w	- Oil in water
o/o	- Oil in oil
P	- Power density
W/m^3	- Watt per meter cubic
Hz	- Hezt
f	- Frequency
ε_0	- Permittivity of free space
ε_r	- Loss factor of the material to be heated
E	- r.m.s. electric field intensity
r.m.s.	- Root mean square
V/m	- Volt per meter
MASD	- Microwave accelerated steam distillation
SD	- Steam distillation
MAE	- Microwave assisted extraction
EMO	- Elba microwave oven
MHz	- Mega Hezt
H	- Height
D	- Diameter
V	- Volt
W	- Width
°C	- Degree celcius
ml	- Mililiter
rpm	- Revolutions per minute
dT/dt	- Rate of temperature
$Csec^{-1}$	- Celscius per second

CHAPTER 1

INTRODUCTION

1.1 Background of study

First of all, coconut oil is not the same as any other oil people use. All the seed oils currently in the American diet are predominately made of triglycerides containing long chain fatty acids. These triglycerides, once ingested, need to be emulsified bile salts. These salts are produced by the liver and stored in the gall bladder. When fats are ingested the bile salts are dumped out of or leave the gall bladder into the small intestine. Hostmark *et al.* (1980) compared the effects of diets containing 10% coconut fat and 10% sunflower oil on lipoprotein distribution in male Wistar rats.

Coconut oil feeding produced significantly lower levels (p = <0.05) of pre-beta lipoproteins (VLDL) and significantly higher (p=<0.01) alpha-lipoproteins (HDL) relative to sunflower oil feeding. Awad (1981) compared the effects of diets containing 14% coconut oil, 14% safflower in tissues in male Wistar rats. Kaunitz and Dayrit (1992) have reviewed some of the epidemiological and experimental data regarding coconuteating groups and noted that the available population studies show that dietary coconut oil does not lead to high serum cholesterol or to high coronary heart disease mortality or morbidity.Kurup and Rajmohan (1995) studied the addition of coconut oil alone to their previous mixed fat diets and report no significant difference. Lim-Sylianco (1987) has reviewed 50 years of literature showing anticarcinogenic effects from dietary coconut oil. These animal studies show quite clearly the nonpromotional effect of feeding coconut oil. Increasingly, over the past 40 years, the American diet has undergone major changes.

Many of these changes involve changes of fats and oils. There has been an increasing supply of the partially hydrogenated trans-containing vegetable oils and a decreasing amount of the lauric acid-containing oils. As a result, there has been an increased consumption of trans fatty acids and linoleic acid and a decrease in the consumption of lauric acid. This type of change in diet has an effect on the fatty acids the body has available for metabolic activities.

Kabara (1978) and others have reported that certain fatty acids (e.g., medium-chain saturates) and their derivatives (e.g., monoglycerides) can have adverse effects on various microorganisms: those microorganisms that are inactivated include bacteria, yeast, fungi, and enveloped viruses. The medium-chain saturated fatty acids and their derivatives act by disrupting the lipid membranes of the organisms (Isaacs and Thormar 1991) (Isaacs *et al*., 1992). In particular, enveloped viruses are inactivated in both human and bovine milk by added fatty acids (FAs) and monoglycerides (MGs) (Isaacs *et al*., 1991) as well as by endogenous FAs and mgS (Isaacs *et al*., 1986, 1990, 1991, 1992; Thormar *et al*., 1987).

Figure 1.1: The coconut tree

1.2 Problem Statement

The emulsion is known to be naturally stabilized by coconut proteins: globulins and albumins and phospholipids (Birosels et al., 1963). However, the coconut milk emulsion is unstable and readily separates into two distinct phases a heavy aqueous phase and lighter cream phase (Cancel, 1979; Gonzales, 1990) .Coconut milk is the natural oil-in-water emulsion extracted from the endosperm of mature coconut either with or without the addition of water (Seow and Gwee, 1997). It contains fat, water, carbohydrate, protein and ash with the major components being water and fat (Tansakul and Chaisawang, 2005). Gravity separation may be too slow because of closeness of the densities of the particles and the fluid, or because of association forces holding the components together.

1.3 Research Objectives

The main aim of this particular research work is to develop a generic but efficient and sustainable water/coconut oil separation method through process intensification and integration based on the application of microwave heating technology. The following will be the tasks or objectives of this study.

1. To examine the demulsification of coconut oil milk by microwave heating using batch Process system
2. To investigate characteristics of coconut oil and water phases
3. To test a model of emulsions and their characteristics
4. Determine the mechanism of coconut oil milk demulsification

1.4 Research Scopes

To accomplish the objective of this study, the scopes of this work focuses on:

- To study the effect of varying the microwave power generation (720 and 540 watts) in the extraction processes.

- To analyze the overall potential of microwave-radiation method as an alternative to the conventional method.
- To characterise coconut oil in terms of chemical and physical properties

CHAPTER 2

LITERATURE REVIEW

2.1 A review of coconut milk

Coconut milk is a milky white oil-in-water emulsion. It is obtained from extraction of coconut flesh with or without added water. It contains fat, water, carbohydrate, protein, and ash with the major components being water and fat. Coconut milk is one of the popular cooking ingredients in Thailand. Among the popular Thai food dishes using coconut milk are curries and dessert. The importance of coconut milk to Thai industries has prompted food scientists and food engineers in this country to develop new products from coconut milk for use as ingredients in household recipes both for the Thai market and for export. Generally, food composition and temperature are the important factors affecting thermal properties (Mohsenin, 1980; Sweat, 1995; Rahman, 1995; Saravacos& Maroulis, 2001). Choi and Okos (1986) developed general models for the prediction of thermal properties of food products as functions of contents of basic food components (i.e., fat, protein, moisture, carbohydrate, fiber, and ash) and their thermal properties (i.e., thermal conductivity, specific heat, and thermal diffusivity).

2.2 A review of emulsion

Emulsion are class od disperse systems consisting of two immiscible liquids.(Tadros,ThF.,2005). The liquid droplets (the disperse phase) are dispersed in a liquid medium (the continuous phase). Several classes of emulsion may be distinguished, namely oil-in-water (O/W), water-in-oil (W/O) and oil-in-oil (O/O). Although emulsion systems have been widely used in many industrial fields, the formation of an emulsion is not always desirable in chemical industries. Formation of emulsions in solvent extraction processes is especially undesirable, since the processes are stopped until the emulsions are separated into oil and water.

The latter class may be examplified by an emulsion consisting of a polar oil (e.g. propylene glycol) dispersed in a nonpolar oil (paraffinic oil), and vise versa. In order to disperse two immiscible liquids a third component is required, namely the emulsifier is cricial not only for the formmation of the emulsion but also for its long-term stability.(Binks,B.P.(ed),1998). Below is the picture to distinguish between O/W and W/O.

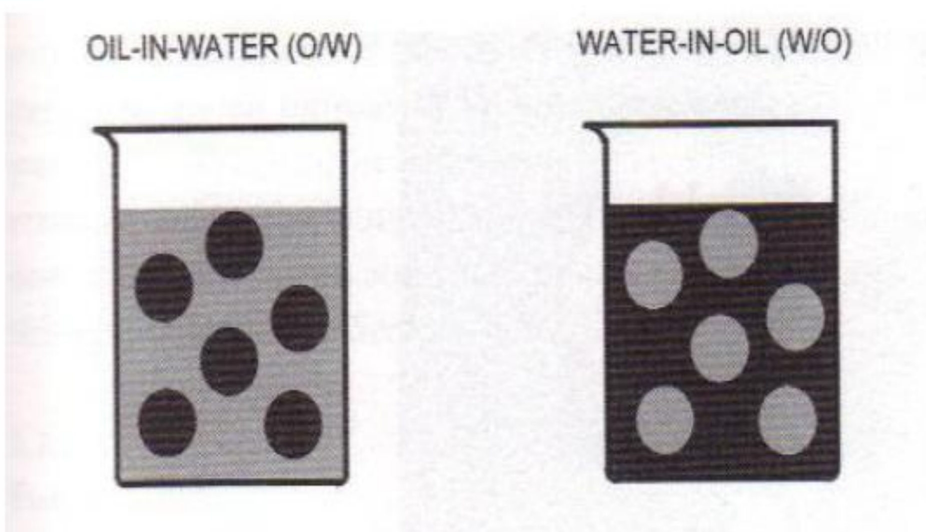

Figure 2.1: Oil-in-water emulsion (O/W) and water-in-oil emulsion (W/O)

2.3 Emulsion characteristics

One of the most important characteristics of emulsions is their inherent instability. Even though the dispersed drops are small, gravity exerts a measurable force on them and over time they coalesce to form larger drops which tend to either settle to the bottom or rise to the top of the mixture. This process ultimately causes the internal and external phases to separate into the two original components. Depending on how the emulsion is formulated and the physical environment to which it is exposed, this separation may take minutes, months, or millennia.

2.4 Separation Process

In chemistry and chemical engineering, a separation process is used to transform a mixture of substances into two or more distinct products. The separated products could differ in chemical properties or some physical property, such as size, or crystal modification or other.

Separation processes can essentially be termed as mass transfer processes.The classification can be based on the meaning of separation, mechanical or chemical. The choice of separation depends on the pros and cons of each. Mechanical separations are usually favored if possible due to the lower cost of the operations as compared to chemical separations. Systems that can not be separated by purely mechanical means can be separated by chemical separation as the remaining solution. The mixture could exist as a combination of any two or more states:

- solid-solid
- solid-liquid
- solid-gas
- liquid-liquid
- liquid-gas
- gas-gas
- solid-liquid-gas mixture

Almost every element or compound is found naturally in an impure state such asa mixture of two or more substances. So that, some method is needed to separate this mixture into its individual components. Separation applications in the field of chemical engineering are very important to separate this mixture.

2.5 Types of separation processes

- Adsorption
- Centrifugation and Cyclones – when the mixture of compound have the density differences
- Chromatography -involves the separation of different dissolved substances as they travel through a material. The dissolved substances are separated based on their interaction with the stationary phase.
- Crystallization
- Decantation
- Demister (Vapor) - removing liquid droplets from gas streams
- Dissolved air flotation - suspended solids are encouraged to float to the top of a fluid by rising air bubbles.

- Distillation - used for mixtures of liquids with different boiling points, or for a solid dissolved in a liquid.
- Drying - removing liquid from a solid by vaporizing it
- Electrophoresis Organic molecules - such as protein are placed in a gel. A voltage is applied and the molecules move through the gel because they are charged. The gel restricts the motion so that different proteins will make different amounts of progress in any given time.
- Elutriation
- Evaporation
- Extraction
- Leaching
- Liquid-liquid extraction
- Solid phase extraction
- Flocculation - density differences utilization a flocculants such as soap or detergent
- Fractional freezing
- Filtration. Mesh, bag and paper filters - used to remove large particulates suspended in fluids, eg. fly ash, while membrane processes including microfiltration, ultrafiltration, nanofiltration, reverse osmosis, dialysis.

2.6 Emulsion breaking or demulsification

Demulsification is a process of oil and water (o/w) separation from emulsions (L.L. Schramm,1992).Typical demulsification techniques include thermal, electrical, chemical, acoustic, or mechanical methods(G. He,G.Chen, 2003). The demulsification process is necessary in many applications such as environmental technology, painting, petroleum industry and waste- water treatment.

2.7 Introduction of Microwave

Microwaves are non –ionizing electromagnetic waves of frequency between 300 MHz to 300 GHz and positioned between the X-ray and infrared rays in the electromagnetic spectrum (M. Letellier and H.Budzinski, 1999). Microwave heating is now an establish technique in industry.Microwave heating has found applications in many other sectors such as plastic industry, chemical industry and other small industries such wood and textile industries (Yoshida et.al., 1993). In the past 20 years, microwave (MW) energy has been widely applied in food and chemical processing for heating, thawing (melting), sintering of ceramics, and many others. The main advantages in microwave heating are, it gives a clean and safe energy source and a better heating uniformity in a relatively short time in comparison with other heating technique. Other advantages of microwave method are reduces energy consumption, smaller quantity of waste product, better product with lower cost and microwaves heat the solvent or solvent mixture directly (Marie E. Lucchesi et al.,2004). Microwave radiation has also been exploited for demulsification as an alternative method for the separation, with promising results, obtained by (Xia et al.,2003). They have proved that microwave radiation is a very effective method for demulsification of o/w emulsion. They compared the results performed in an oil-bath or microwave oven and samples treated with microwave radiation have improved the demulsification rate by an order of magnitude (Xia et.al.,2003). Microwave radiation destabilizes emulsions in several ways: with high temperature and by selective absorption of microwave energy by surfactant and oil molecules, rather then ice, which is known as having low loss factor for MW. Higher temperature reduces the continuous phase viscosity and breaks the outer film of the drops, thus allowing the coalescence.(C. Vega, M. Delgado,2002).

2.8 Microwave theory

Industrial heating depends on the efficient conversion of microwave energy to thermal energy. Microwave energy is a non ionizing radiation that causes molecular motion by migration of ions and dipole rotations, but does not cause changes in molecular structure and wavelengths ranging from a few cm to few mm. This conversion occurs when a material containing suitable molecules is placed in an electric field alternating in radio or microwave frequencies (I.A.Ali and A.M.S.Al-Amri, 1997). Heating is produced by a rapid reversal of polarization of individual molecules (space charge polarization and orientation polarization). The properties of material which determine the degree of interaction of its molecules with microwaves and hence the effectiveness of heating is the dielectric constant and the loss factor of the material at the frequency under consideration. The relation between microwave power dissipated per unit volume and the properties of the material is:

$$P = 2\pi f \varepsilon_o \varepsilon_r'' |E|^2$$

Where P power density in W/m3, f is the frequency in(Hz), ε_0 is the permittivity of free space (Farad/m), ε_r is the loss factor of the material to be heated and E is the r.m.s. electric field intensity in V/m. In conventional thermal processing, energy is transferred to the material through convection, conduction, and radiation of heat from the surfaces of the material. In contrast, microwave energy is delivered directly to materials through molecular interaction with the electromagnetic field. In the heat transfer, energy is transferred due to thermal gradients, but microwave heating is the transfer of electromagnetic energy to thermal energy and is energy conversion, rather than heat transfer. This difference in the way energy is delivered can result in many potential advantages to using microwaves for processing of materials.

Because microwaves can penetrate materials and deposit energy, heat can be generated throughout the volume of the material. The transfer energy does not rely on diffusion of heat from the surfaces and it is possible to achieve rapid and uniform heating of thick materials. In recent literature, many researches reported non–thermal phenomena that have been broadly termed "microwave effects''. Examples for microwave effect include enhanced reaction rates of thermosetting resins during microwave curing Marand et al. (1992) and faster densification rates in ceramics sintering Janney et al. (1991). As materials are processed, they often undergo a physical and structural transformation that affects the dielectric properties. Thus, the ability of microwave to generate heat varies during the process. Sharp transformations in the ability of microwave to generate heat can cause difficulties with process modeling and control.

2.9 Microwave Methods

Microwave is used in other process such as microwave steam distillation, extraction, digestion and others.

2.9.1 Microwave steam distillation

Microwave accelerated steam distillation (MASD) is an original combination of microwaves and steam distillation (SD). The apparatus is relatively simple. This process thus frees essential oil from plant material which is evaporated by steam. The advantages of the steam distillation (namely, continuous contact of the plant material with clean extractant “steam” and not solvent extraction required) remain in the new device MASD, which , in addition, is quicker and allows substantial saving in energy and costs (F.Chemat et.al, 2005).

2.9.2 Microwave assisted extraction (MAE)

Microwave Assisted is a simple technique that provides a novel way of extracting soluble product into fluid, from a wide range of materials, helped by microwave energy (Paree et.al, 1994). The technique can be applied to both liquid phase extraction and gas phase extraction.

2.9.3 Microwave demulsification

The concept of microwave demulsification was first introduced by Klaika (1978) and Wolf (1986 & 1983) in their patent applications.Klaika conducted several other field tests after his patent was authorized, and the results were encouraging.(Fang et al,1989). Later, Fang et al. presented a demulsification model for 1:1 and 3:7 water-in-oil systems under microwave radiation.The experimental results showed that the percentage of water separated from the emulsions was higher than 80% under certain conditions (Fang et al.,1995). Microwave radiation has also been exploited for demulsification as an alternative method for the separation, with promising results, obtained by Xia et al. They have proved that microwave radiation is a very effective method for demulsification of o/w emulsion (Xia et al.,2003).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

The research methodology carried out in this study is discussed in this chapter. A new set of microwave generating equipment was set up as the experimental rig to obtain the separation efficiency data. There are two part of this chapter which is the procedure of the microwave experimental rig for demulsification part and an analysis of the sample using Brookfield equipment for stability part.

3.2 Raw Material

The raw material needed to run this experiment is coconut milk.

3.2.1 Coconut milk

Coconut milk is a sweet, milky white cooking base derived from the meat of a mature coconut. The colour and rich taste of the milk can be attributed to the high oil content and sugars. In Malaysia, Brunei and Indonesia coconut milk is called *santan* and in the Philippines it is called *gata*. In Thailand it is called *ga-ti* (กะทิ) and used in many of the Thai curries. In Brazil, it is called *leite de coco* (literally, *coconut milk*). It should not be confused with coconut water (coconut juice), which is the naturally-occurring liquid found inside a coconut.

3.3 Equipment and apparatus

The equipment and apparatus used in this experiment are microwave, beaker, cylinder measurement and gloves, thermometer, spatula and aluminum foil.

3.3.1 Microwave

Figure 3.1 below shows the microwave generating equipments which is Elba domestic microwave oven model: EMO 2305 is modified and connected with three thermocouples and use in heating coconut oil milk samples (for batch heating process). The details of the Elba domestic microwave oven was: its power consumption is 230-240 V~50Hz, 1400 Watts (microwave), 230 V at 1000 Watts (Heater) and its rated power outlet is 900 Watts at operation frequency of 2450 MHz. The oven cavity dimensions are: 215 mm (H)*350mm (W)* 330 mm (D), and oven capacity 23 Litres. Figure 3.1 shows theschematic details of Elba domestic microwave.

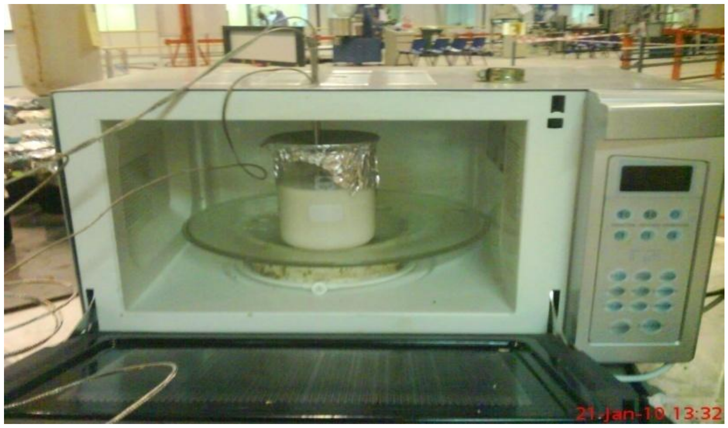

Figure 3.1: Microwave heating

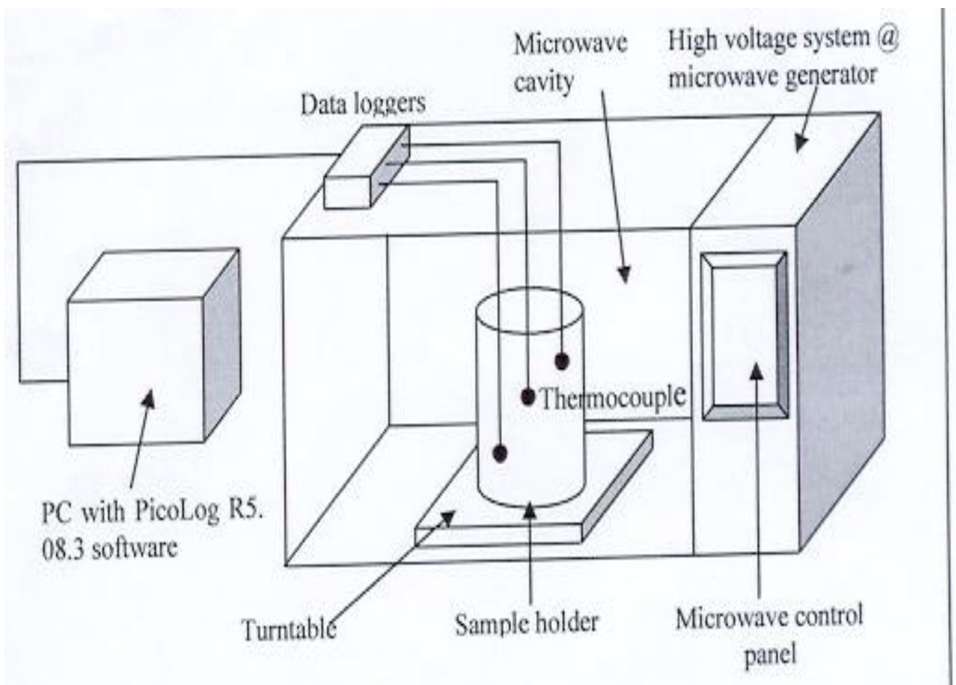

Figure 3.2 Microwave heating experimental rig

3.4 Experimental Works

3.4.1 Microwave experimental Procedure

Before run the experiment, the pre-start up procedure is performed. A 400ml of coconut milk is prepared. The temperature of the coconut milk must be in room temperature which is 27 °C. Then the microwave is set at 720W for 5 minutes. Then the coconut milk is heated using microwave. After that the sample is take out from microwave to 250ml measurement cylinder which is settling process is happened. The procedure mentioned above is repeated for the parameter 720W; 7 minutes, 540W; 5 minutes, 540W; 7 minutes. Each sample is run for 3 times per sample. Lastly the data is recorded.

3.4.1.1 Experiment of demulsification of coconut milk

The microwave heating is set up.

↓

The 400 ml coconut milk is prepared. The cylinder measurement contents coconut milk heating is covered by the aluminums foils to avoid the heat move to surrounding.

↓

The time and the power of the mixture heating are set.
Heat the ethyl acetate mixture using microwave heating

↓

The coconut milk is heated using microwave heating.

The samples from microwave heating is collected and poured into the 250 ml cylinder measurement for settling process.

↓

The procedure 2 until 5 with different times and different powers is repeated.

3.4.1.1 Experiment of stability of coconut milk

The sample is placed in the Brookfield sample part.

↓

The temperature and rpm is set at 25°C and 50 rpm.

↓

The Brookfield is started.

↓

The reading of viscosity, shear stress and shear rate is recorded.

↓

The procedures of 1 to 4 is repeated for temperature of 50°C,70°C and 90°C and for 100 rpm,150 rpm and 200 rpm.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This present investigation, the various factors affecting the stability and viscosity of water in oil emulsions. These factors are the oil content of the emulsion, the water content in the emulsion, agitation speed, and shear stress and shear rate. This study has four objectives which are to examine the demulsification of coconut oil milk by microwave heating using batch process system, to investigate characteristics of coconut oil and water phases, to test the model of emulsions and their characteristics and determine the mechanism of coconut oil milk demulsification.

4.2 Results (emulsion stability)

4.2.1 Emulsion Rheology

Rheology is a study of deformation or flow mechanism from the application of a given force to the system. Its technique can be used to study the structure of emulsion ranging in consistency from fluids to solids. In response to a given force, emulsion systems can demonstrate different behavior namely Newtonian and more complex non-Newtonian flow depending upon their internal (dispersed) phase volume ratio.

4.2.2 Effects of the viscosity on the emulsion stability

As shown in figure 4.1, which is a plot of viscosity as a function different temperature, it is clear from this figure 4.1, there is a correlation between viscosity and temperature, which is; as increasing the temperature, the viscosity of the emulsion is decrease. This is because the density of the emulsion is decrease when the temperatures increase. When the temperature increase the attraction between the molecular bonds will become decrease, so the shear stress becomes less. The non-Newtonian fluid is a fluid in which the viscosity varies depending upon the shear stress and also time. In other words, when shear rate increase the viscosity will decrease and the temperature is increase. So the emulsion is Pseudoplastic non- Newtonian fluid.

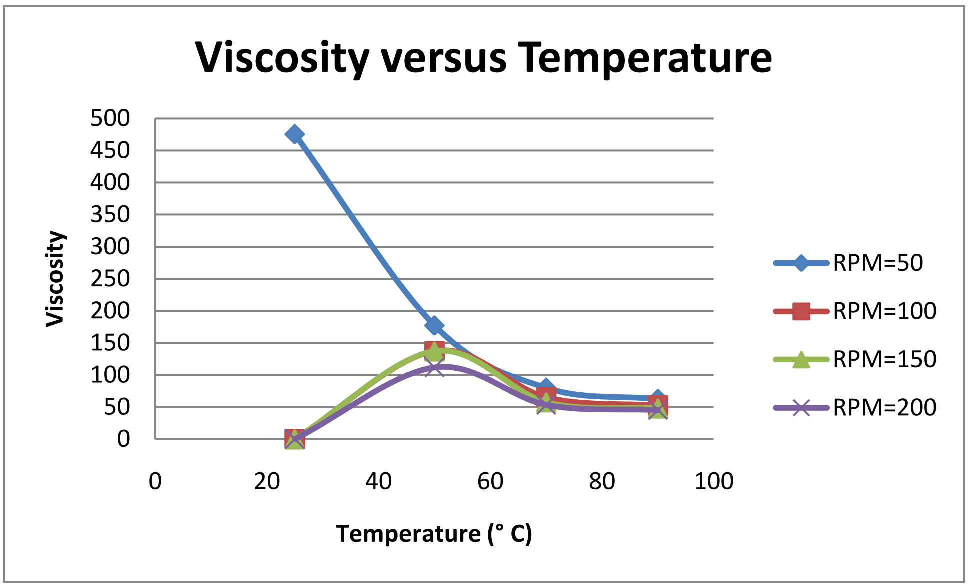

Figure 4.1 Effects the viscosity on emulsion stability

Table 4.1 Relation between temperature and viscosity

Temperature (°C)	Viscosity			
	50	100	150	200
25	475.1	0	0	0
50	177	137.1	137.1	111.6
70	79.8	65.1	57.6	53.4
90	62.4	52.2	48	45.3

4.2.3 Effect of viscosity with shear rate

The experimental data obtained for coconut milk are shown in figure 4.2. This was obtained for each experimental condition and exhibited non-Newtonian pseudoplastic behavior. The results showed that viscosity decreased with increasing shear rate for all samples. As the shear rate increased, the particle interaction was deformed and eventually disrupted which resulted in the size reduction of the flocs and resulted in decreasing of viscosity. At higher shear rate, the viscosity reached a constant value because all of flocs and large particles were completely disrupted. Therefore, only individual and small particles remained in the system (McClements, 1999). The emulsions are pseudoplastic non Newtonian fluid.

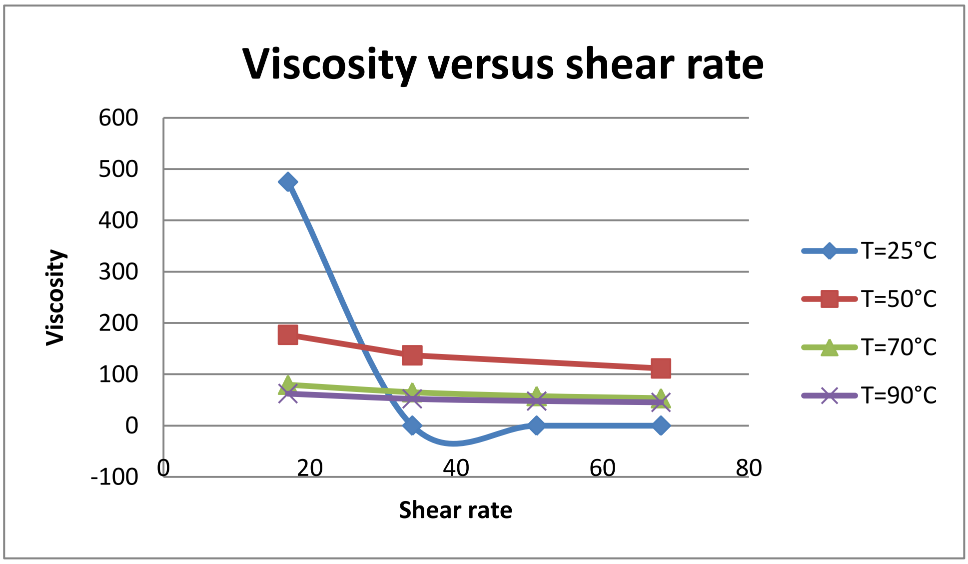

Figure 4.2 Effect of viscosity with shear rate

Table 4.2 Effect of viscosity with shear rate

RPM		Temperature (°C)			
		25	50	70	90
50	Shear rate	17	17	17	17
	Viscosity	475.1	177	79.8	62.4
	Shear rate	34	34	34	34
100	Viscosity	0	137.1	65.1	52.2
150	Shear rate	51	34	51	51
	Viscosity	0	137.1	57.6	48
200	Shear rate	68	68	68	68
	Viscosity	0	111.6	53.4	45.3

4.2.4 Effect of shear stress with shear rate

From the figure 4.3 shows that the shear stress increase when the shear rate increase. The emulsion at all temperature is Newtonian fluid. As depicted in figure 4.3, a Newtonian fluid will exhibit a linear relationship between shear stress and shear rate and, hence the viscosity is independent of the applied shear condition.

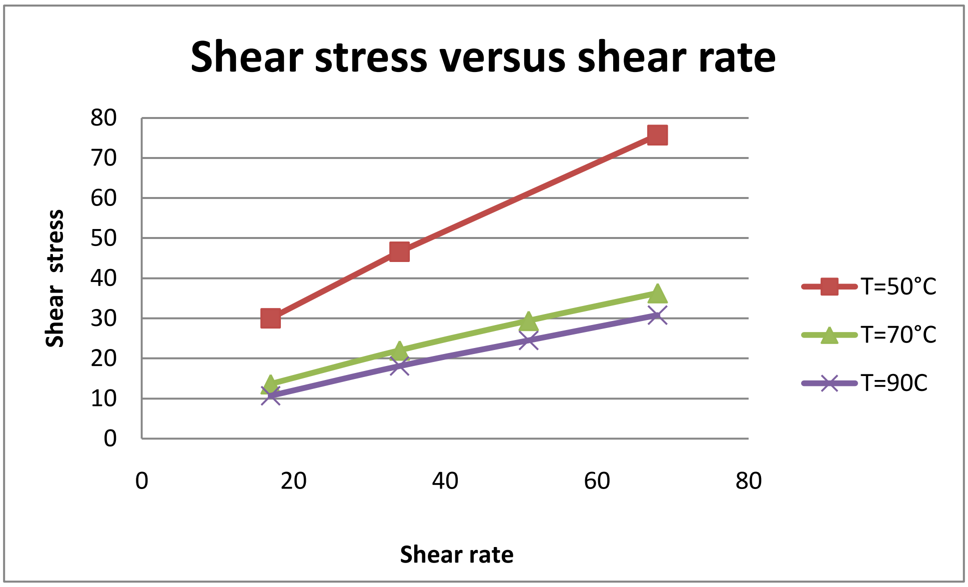

Figure 4.3 Effect of shear stress with shear rate

Table 4.3 Effect of shear stress with shear rate

RPM	**Temperature (°C)**			
		50	70	90
50	Shear rate	17	17	17
	shear stress	30	13.6	10.7
100	Shear rate	34	34	34
	shear stress	46.6	22	18.1
150	Shear rate	34	51	51
	shear stress	46.6	29.4	24.5
200	Shear rate	68	68	68
	shear stress	75.7	36.3	30.8

4.3 Demulsification

4.3.1 Effect on microwave radiation

From figure 4.4 and 4.5 shows the experimental results of microwave radiation for coconut milk oil emulsion. Figure 4.4 shows that temperatures of the microwave increase when time increase with different power. For power of 720W, the temperature is increasing highly than 540W of microwave power with the same time. For example, at 100s the temperature of 540W; 7min is 40.41°C while 720W; 7min is 54.22°C. It is also obvious that, there were a correlation between the radiation time and the rate of temperature increase, as radiation time increase, the rate of temperature (dT/dt) decreases (figure 4.5). Also the rate of temperature (dT/dt) decreases at higher temperatures, this may attributed due to the small dielectric loss of water. The average rates of temperatures increases for sample of coconut milk oil at 540W; 5min is 0.556998 $Csec^{-1}$, at 540W; 7 min is 0.468275 $Csec^{-1}$, at 720W; 5min is 0.594327 $Csec^{-1}$ and 0.589452 $Csec^{-1}$. Since the purpose of heating oil in water emulsions with the microwave is to separate water from oil, therefore, the separation efficiency of coconut milk oil is calculated and the result have shown in figure 4.7.

For sample of 540W;5min,540W;7min,720W;5min and 720W;7min at microwave radiation time at 210 second the water separation was found is 25%,39.33%,42.5% and 26% respectively.

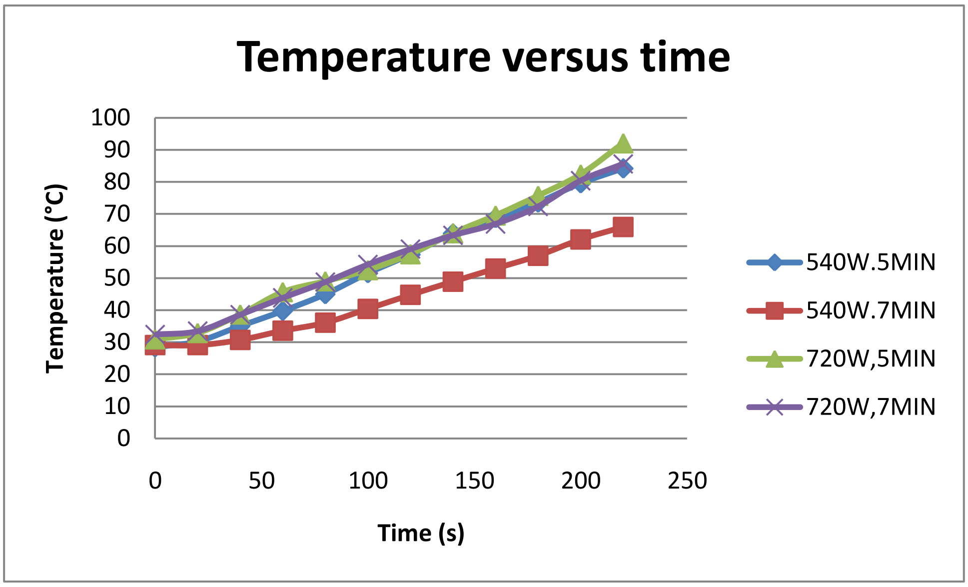

Figure 4.4 Relation between temperatures versus time

Table 4.4 Relation between temperature and time

Time(s)	T (°C)			
	540W,5MIN	540W,7MIN	720W,5MIN	720W,7MIN
0	28.45	29.1	30.92	32.43
20	30.28	29.12	32.89	33.45
40	35.05	30.73	38.66	38.56
60	39.76	33.61	45.65	43.82
80	44.98	36.09	49.03	48.76
100	51.54	40.41	52.51	54.22
120	57.35	44.76	57.48	59.03
140	63.91	48.9	64.03	63.32
160	68.72	52.96	69.54	66.88
180	73.55	56.97	75.69	72.29
200	79.57	62.02	82.36	80.37
220	84.21	65.91	92.09	85.58

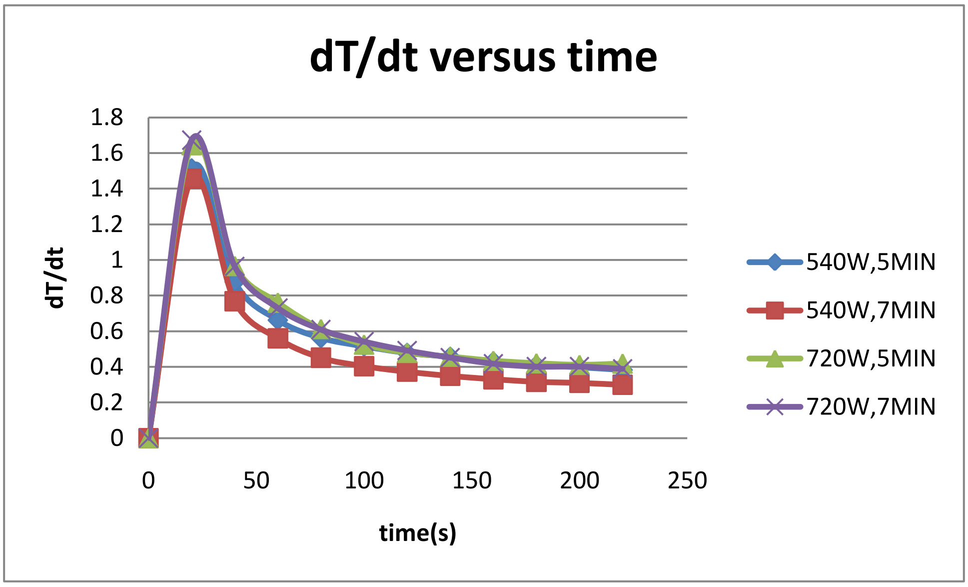

Figure 4.5 Heating rate versus microwave radiation time

Table 4.5 Heating rate of microwave radiation

Time (s)	Temperature (° C)			
	540W,5MIN	540W,7MIN	720W,5MIN	720W,7MIN
0	0	0	0	0
20	1.514	1.456	1.645	1.673
40	0.876	0.768	0.967	0.964
60	0.663	0.560	0.761	0.730
80	0.562	0.451	0.613	0.619
100	0.515	0.404	0.525	0.542
120	0.478	0.373	0.479	0.492
140	0.457	0.349	0.457	0.452
160	0.429	0.331	0.435	0.418
180	0.409	0.316	0.421	0.402
200	0.398	0.310	0.412	0.402
220	0.383	0.299	0.419	0.389

4.3.2 Effect of the amount of water separation

Figure 4.6 show the effect of the amount of water separation on demulsification process. From the observation, the volume of water separation for all samples is increase when the time settling is increase. When the volume of water separation is less, the emulsion is more stable.

When the water quantity in the emulsion sample is small, the viscosity of that emulsion is high. So, the molecules velocity in the emulsion is small. Then, the molecules is very hard to move and separate water from the emulsion. Besides that, the intermolecular force between the water and oil in the emulsion is high. These molecules need more energy to break the intermolecular force. So, the microwave heating is used to supply the energy. After the energy supply from heating process, the time taken to break the bond between the molecules is decrease. From the observation, at 210 min settling time, the maximum volume of water separated from the emulsion microwave power of 540W; 5Min is 25 %, for power 540W; 7Min is 39.33 %, for power 720W; 5Min is 42.5% and for power 720W; 7Min is 26%.

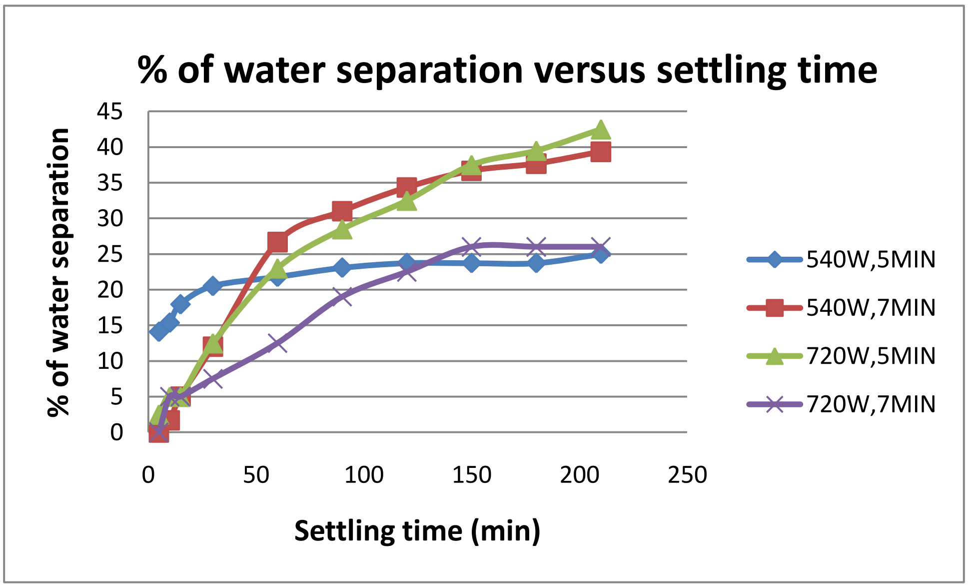

Figure 4.6: Effect of volume of water separation on emulsion stability

Table 4.6 Effects of percent of water separation on emulsion stability

Time(min)	Percent (%) of water separation			
Samples	540W,5MIN	540W,7MIN	720W,5MIN	720W,7MIN
5	14.1.0	0.00	2.5	0.00
10	15.38	1.66	5.00	5.00
15	17.95	5.00	5.00	5.00
30	20.51	12.00	12.50	7.50
60	21.79	26.67	23.00	12.50
90	23.07	31.00	28.5	19.00
120	23.72	34.33	32.5	22.50
150	23.72	36.66	37.5	26.00
180	23.72	37.66	39.5	26.00
210	25.00	39.33	42.5	26.00

4.3.3 Effect of the amount of oil separation

Figure 4.7 show the effect of the amount of oil separation on demulsification process. From the observation, the volume of oil separation for all samples is increase when the time settling is increase. When the volume of oil separation is less, the emulsion is more stable. When the oil quantity in the emulsion sample is small, the viscosity of that emulsion is high. So, the molecules velocity in the emulsion is small. Then, the molecules is very hard to move and separate water from the emulsion. Besides that, the intermolecular force between the water and oil in the emulsion is high. These molecules need more energy to break the intermolecular force. So, the microwave heating is used to supply the energy. As a result, oil separate in a small volume will makes the emulsion more stable.From the observation, at 210 min settling time, the maximum percent of oil separated from the emulsion microwave power of 540W; 5Min is 4.87 %, for power 540W; 7Min is 14.70 %, for power 720W; 5Min is 1.47 % and for power 720W; 7Min is 4.51 % respectively.

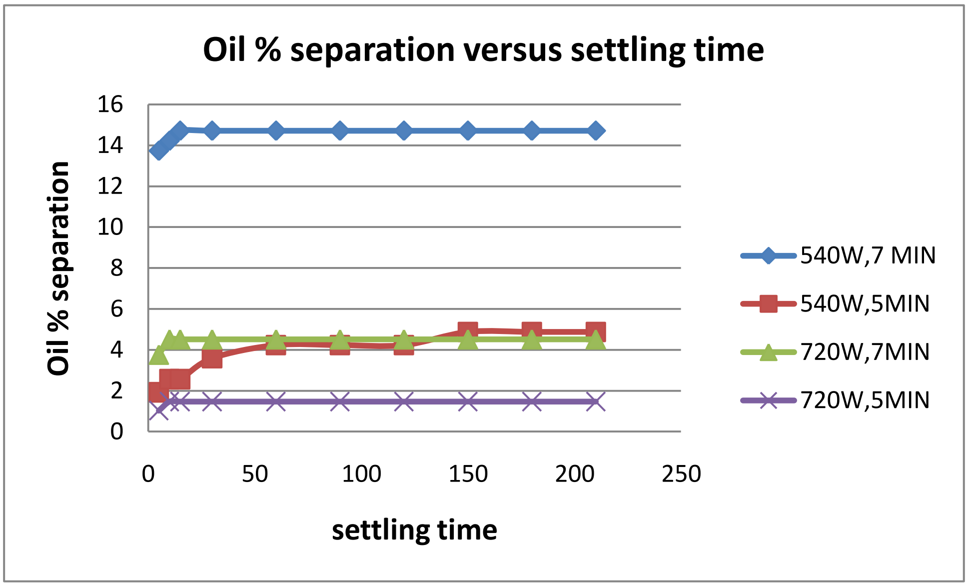

Figure 4.7: Effects of percent of oil separation

Table 4.7 Effects of percent of oil separation

time(min) Samples	Percent (%) of oil separation			
	540w,5min	540w,7min	720w,5min	720w,7min
5	1.92	13.72	1.02	3.75
10	2.56	14.21	1.47	4.51
15	2.56	14.70	1.47	4.51
30	3.58	14.70	1.47	4.51
60	4.23	14.70	1.47	4.51
90	4.23	14.70	1.47	4.51
120	4.23	14.70	1.47	4.51
150	4.87	14.70	1.47	4.51
180	4.87	14.70	1.47	4.51
210	4.87	14.70	1.47	4.51

CHAPTER 5

CONCLUSION

The microwave heating process was successfully examined for water, oil and emulsion samples. Results of this study showed that, microwave radiation separated water from emulsion in a short time to reach at stable state than separation of emulsion by conventional heating method. When heat was applied, molecule become energized then give results as high volume of water separation in a short processing time compared to demulsification at room temperature. This study had found that microwave increased both the speed and efficiency of demulsification.

Microwave heating technology can be an alternative way in breaking oil-in-water emulsion and enhances gravity sedimentation to separate the emulsion into water and oil layers. Demulsification of oil-in-water emulsion by using microwave heating are suggested as alternative method because of its unique characteristics which is fast, cheap and very effective. Furthermore, this technique also is a new technique that not required chemical addition.

CHAPTER 6

RECOMMENDATION

6.1 Use a fresh coconut milk to get a better yield.

In this study the coconut milk obtained from the market in a large amount then put into the freezer. So, the coconut milk must be at 27 °C before heating. The structures of coconut milk also different after placed in the freezer. So, the fresh coconut milk will give more yield oil-water separation.

6.2 Change the batch system to continuous system

In this study the process system use is batch system. So, for the next study, it is recommend to change the process system into a continuous system. The improvement will be done by connect the microwave with the pump or tube to transfer the coconut milk after heating to settling tank.

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APPENDIX A

Experimental results for stability of coconut oil milk.

Temperature(°C)	RPM	Shear Rate	Shear Stress	Viscosity
25	50	17.0	79.1	475.1
	100	34.0	-	-
	150	51.0	-	-
	200	68.0	-	-
50	50	30.0	17.0	170.0
	100	34.0	46.6	137.0
	150	34.0	46.6	137.0
	200	68.0	75.7	111.6
70	50	17.0	13.6	79.8
	100	34.0	22.0	65.1
	150	51.0	29.4	57.6
	200	68.0	36.3	53.4
90	50	17.0	10.7	62.4
	100	34.0	18.1	52.2
	150	51.0	24.5	48.0
	200	68.0	30.8	45.3

APPENDIX B

Experimental results of demulsification process.

Time(s)	T (°C)			
	540W,5MIN	540W,7MIN	720W,5MIN	720W,7MIN
0	28.45	29.1	30.92	32.43
20	30.28	29.12	32.89	33.45
40	35.05	30.73	38.66	38.56
60	39.76	33.61	45.65	43.82
80	44.98	36.09	49.03	48.76
100	51.54	40.41	52.51	54.22
120	57.35	44.76	57.48	59.03
140	63.91	48.9	64.03	63.32
160	68.72	52.96	69.54	66.88
180	73.55	56.97	75.69	72.29
200	79.57	62.02	82.36	80.37
220	84.21	65.91	92.09	85.58