RECLAMATION OF WASTE COOKING OIL METHYL ESTER

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A report submitted
in partial fulfillment of the requirements for the degree of
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2019

DECLARATION

I declare that this thesis entitled “RECLAMATION OF WASTE COOKING OIL METHYL ESTER is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have checked this report entitled "Reclamation Of Waste Cooking Oil Methyl Ester" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

In the name of Allah SWT the Most Beneficent and Merciful, all praises and glory be upon Him. Blessing and Greeting upon our beloved prophet Muhammad SAW, his family and companions.

First and foremost, I would like to say Alhamdulillah to Allah S.W.T. for giving strength, ideas and healthy body during the completing my progress report final year project. With the blessing from our creator Allah S.W.T., the progress report had completed as the way it is.

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ABSTRACT

Liquid insulation is a vital medium in power system especially transformers which acts as insulation as well as coolant. As the year passed, liquid insulation in the transformer degrades and begins to lose its function as an insulation medium, which affects the transformer's life and efficiency. The problem occurs when the waste oil is converted into new mineral oil. Mineral oil in transformers can affect the environment if accidents occur during working hours. The decision of replacing, refurbishing or repairing a service aged power transformer requires considering several factors, especially the cost and time to execute the work. In order to prevent that from happen, vegetable oil is used as an alternative insulation liquid for transformer oil because it is more environmental friendly. Catalyst which is sodium hydroxide (NaOH) content is analyzed for WCO methyl ester transesterification. In addition to analyzing the differences in the sequence between recycling and transesterification in an opportunity to impact the oil quality improvement process. The study are carried out to verify the results using the optimum reclamation process parameters, it is found that there is significant improvement in the AC breakdown voltage, total acid number (TAN), moisture and Ultraviolet-Visible (uv-vis) for the reclaimed transformer oil. This method is believed to be an independent tool for determining the optimal parameters for the recovery process for methyl ester waste oil.

ABSTRAK

Penebat cecair adalah medium penting dalam sistem kuasa terutama transformer yang berfungsi sebagai penebat serta penyejuk. Apabila tahun berlalu, penebat cecair dalam pengubah merendahkan dan mula kehilangan fungsinya sebagai medium penebat, yang mempengaruhi kehidupan dan kecekapan pengubah. Masalahnya berlaku ketika minyak buangan diubah menjadi minyak mineral baru. Minyak mineral dalam transformer boleh menjejaskan alam sekitar sekiranya berlaku kemalangan semasa waktu bekerja. Keputusan penggantian, pembaikian atau pembaikan perkhidmatan pengubah kuasa yang berusia memerlukan mengambil kira beberapa faktor, terutama kos dan masa untuk melaksanakan kerja. Untuk mengelakkannya daripada berlaku, minyak sayuran digunakan sebagai cecair penebat alternatif untuk minyak pengubah kerana ia lebih mesra alam sekitar. Kandungan pemangkin yang natrium hidroksida (NaOH) dianalisa untuk transesterifikasi metil ester WCO. Di samping menganalisis perbezaan dalam urutan antara kitar semula dan transesterifikasi dalam peluang untuk memberi kesan kepada proses peningkatan kualiti minyak. Kajian ini dijalankan untuk mengesahkan keputusan menggunakan parameter proses penambakan optimum, didapati terdapat peningkatan yang signifikan dalam ketahanan voltan AC, jumlah asid (TAN), kelembapan dan Ultraviolet-Visible (uv-vis) untuk ditarik balik minyak pengubah. Kaedah ini dipercayai sebagai alat bebas untuk menentukan parameter optimum untuk proses pemulihan untuk minyak buangan metil ester.

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LIST OF SYMBOLS AND ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
FYP	-	Final Year Project
WCO	-	Waste Cooking Oil
WCOME	-	Waste Cooking Oil Metyl Ester
BdV	-	Breakdown Voltage
TAN	-	Total Acidity Number
IEEE	-	Institute of Electrical and Electronic Engineer
ASTM	-	American Society for Testing and Materials
uv-vis	-	Ultraviolet–visible
FTIR	-	Fourier-Transform Infrared
IR	-	Infrared
NaOH	-	Sodium Hydroxide
g	-	Gram

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CHAPTER 1

INTRODUCTION

1.1 Background

Power transformers are the backbone of the world's electricity and distribution systems. The price of power transformers is exorbitant and therefore, frequent maintenance is necessary to ensure that these systems are highly reliable during their operation. The service life of mineral insulating oils is typically 30 to 40 years for power transformer applications [1].

Insulating liquids are generally preferable because these liquids serve a dual purpose are insulator and coolant. It is expected that mineral oils will continue to be in use for at least a decade and it is known that the dielectric properties of the oils will be altered as a consequence of aging, which will degrade the efficiency of the transformers. In addition, it is common knowledge that the insulating systems of transformers will deteriorate gradually due to their high operating temperatures as well as high levels of moisture and oxidation of the transformer oils. The insulating systems performance will decrease due to changes in the chemical structures of the dielectric media as a result of high thermal stresses which adversely affect the transformer operation and if left unchecked, will lead to catastrophic failure of the transformers [7]. There are three ways to treat insulation oils through re-refining, reconditioning, and reclamation [2], [7].

1.2 Problem Statement

Petroleum based mineral oil has long been used as insulation for the transformer. Mineral oil acts as a cooling and insulating medium in transformer. Transformer mineral oil has been replaced by alternative oils such as vegetable oil. Oil is chosen based on its biodegradability and environmentally friendly nature. Due to the environmental consideration, mineral oil is the poor biodegradability and future scarcity. It can cause pollution and contaminate the soil if there is a heavy leakage.

The mineral oil was extracted from the oil that will run out in the future, and the oil is non - renewable energy [19].

The identification that is satisfied with their nature in different circumstances is the main reason for their application as an insulating liquid in the energy industry. Enhancing the production process and treatment of mineral oil has contributed to a significant price effect, which is one of the key criteria that potential potential transformers consider. Where transformer oil can't be used for a long time. However, the price is still reasonable to make mineral oil still the preferred liquefaction fluid for consumers, although alternative liquids have significantly improved environmental and fire properties. [13].

In addition, the use of waste cooking oil circumvents the problem of oil vs food, which has become a hotly debated issue in recent years. Cooking oil consumption increases and its consistent supply makes waste cooking oils commercially viable. Approximately 3 billion liters of cooking oil are used in Malaysia every year. However, only 30 % of waste oil food is available for biodiesel production which translates to about 10 % of diesel demand in Malaysia. Things look like waste, where demand increases every day. [28]-[29]. In this study, waste cooking oil methyl ester (WCOME) is chooses to be new insulating oil.

1.3 Objectives

The objectives of this project are:

a) To investigate the influences of catalyst for transesterification process of waste cooking oil methyl ester.

b) To investigate the reclamation process to improvement in the mean the breakdown voltage, total acid number, moisture, and ultraviolet-visible.

c) To analyze the sequence of process to improvement waste cooking oil methyl ester.

1.4 Scope of research

The scopes of the research are listed as follow:

a) To analysis the effect of different ratio of alcohol and catalyst for transesterification of waste cooking oil methyl ester.

b) Types of parameters which is weight of the Fuller's Earth adsorbent, stirring speed, and oil temperature for reclamation of waste cooking oil methyl ester.

c) The results for reclamation process of AC breakdown voltage, total acidity number, moisture and ultraviolet-visible.

d) Analysis the sequence of process to improvement waste cooking oil methyl ester.

1.5 Project Outline

This thesis consists of five chapters which are introduction, literature review, methodology, result and conclusion. The first chapter had reviewed the objective and scope of this project with background of study. Next, in chapter two is more focused on the literature review and theory from the research for this project.

In chapter three, the methodology of the project such as reclamation process, transesterification process and procedure for breakdown voltage has been summarized in this chapter. The result and discussion are presented in chapter four. Lastly, conclusion, recommendation and future work are outlined in chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Transformer oil is a type of fluid which may be a type of mineral which is an insulating oil. This oil needs to be through the breakdown of refining and treatment of crude petroleum at the petroleum refineries. The transformer oil works mainly for two purposes, namely liquid insulator in the electric power transformer and two heat release transformers, such as coolant. [19].

In today's uncertain economic climate, it is important to know the situation through the appropriate diagnostic test that fluid paper can be used as the main insulator in the transformer to be harmless and can be used for long periods of time. Today, the development of new laboratory test procedures for liquid insulators in recent years has been a satisfactory result of a cooperative research project designed to improve the life- long conversion of aging power[14]. Some references have been modified to discover alternative methods to maximize the present oil. However, the results are unsatisfactory because the study relates only to the nature of the insulating oil from the suitability of oil as an insulating oil without taking any other relevant factors.

2.2 Transformer Oil

Power transformer is one of the most important parts of transmission power and distribution network in the industry. Meanwhile, the main role of transformer oils provides a thermal insulation. The life and efficiency of the power transformer depends entirely on the quality of the insulating oil that needs to be monitored on an ongoing basis. [14]. There are three types of transformer oil that are mainly used such as mineral oil, ester oil and silicone oil.

2.2.1 Mineral Oil

Mineral oil is one of the most commonly used insulating liquids today. It is used in many electrical devices. Undoubtedly the application of mineral oil produces many positive properties and excellent recognition over the years [13]. Transformer oil based on mineral oil can be produced either from naphtha or paraffin. The Figure 2-1 below shows the elements of mineral oil based transformer oil production.

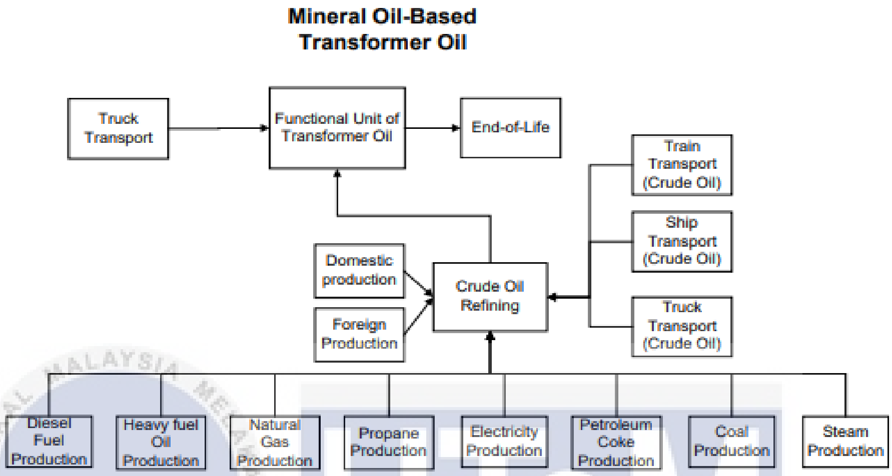


Figure 2-1 : Mineral Oil Based Transformer Oil System Boundaries

2.2.2 Natural Ester

Natural esters are produce from vegetable oil which is manufactured from plant crops. It has good biodegradability but most of natural esters have problem in oxidation stability as other types of insulating liquids. Generally, natural esters for electrical utilization are most commonly come from soya, rapeseed and sunflower oil.

The liquids from natural esters have several characteristics that are recognized in a variety of uses, compared to mineral oils. These characteristics are primarily ecological properties such as biodegradability and non-toxicity, and the operational safety properties of operations that include lightning and high fuels. For this reason, where fire safety and environmental protection play an important role as it is used in the industry. The use of esters filled with transformers is a reasonable solution for today [13].

2.2.3 Palm Fatty Acid Ester (PFAE)

In acknowledgment of increasing global environmental concerns and the need to switch from dependence on fossil fuels to energy needs, the development of transformers with ester- type oils is in progress. This type of oil, palm fatty acid ester (PFAE) is rich in biodegradability and used to replace conventional mineral insulation. Today, the industry leads to an ecosystem-friendly transformer using PFAE as a vegetable-based insect oil. PFAE is a very green and strong high performance oil. Compared with mineral oil, its kinetic viscosity is low and the dielectric constant is high. When used in oil transformers, there is therefore the possibility that we can realize a best design. When it is used as insulating oil, it offers outstanding features in terms of stable supply and oxidation stability [15].

Table 2-1 shows the comparison of physical properties of PFAE, and mineral oil.

Table 2-1 The comparison of physical properties of PFAE, and mineral oil [15].

Item	PFAE	Mineral oil	Remark (condition)
Density (g/cm3)	0.86	0.88	15ºC
Kinetec viscosity (mm2/s)	5.06	8.13	40ºC
Flash point (ºC)	186	152	COC
Pour point (ºC)	-32.5	-45	
Acid Number (mgKOH/g)	0.005	<0.01	
Dielectric constant	2.95	2.2	80ºC
Volume resistivity (Ω. Cm)	7.1 x 1012	7.6 x 1015	80ºC
Dielectric breakdown voltage (kV)	81	70~75	2.5mm

2.3 Transesterification Process

Transesterification is a term used to demonstrate direct conversion of lipid triacylglycerol's by alcohol to an alkyl ester without separating free fatty acids (FFA). In particular, in the presence of an acidic or alkaline catalyst to produce fatty acid esters and glycerol, a triglyceride such as vegetable oil reacts with an alcohol, usually methanol. The catalyst may be acidic or alkaline. Alkaline metal alkoxides such as sodium methoxide and hydroxides are more effective than acid catalysts. The well-known mechanisms of acid and alkaline alcoholysis are depicted in Figure 2-2 [11], [12].

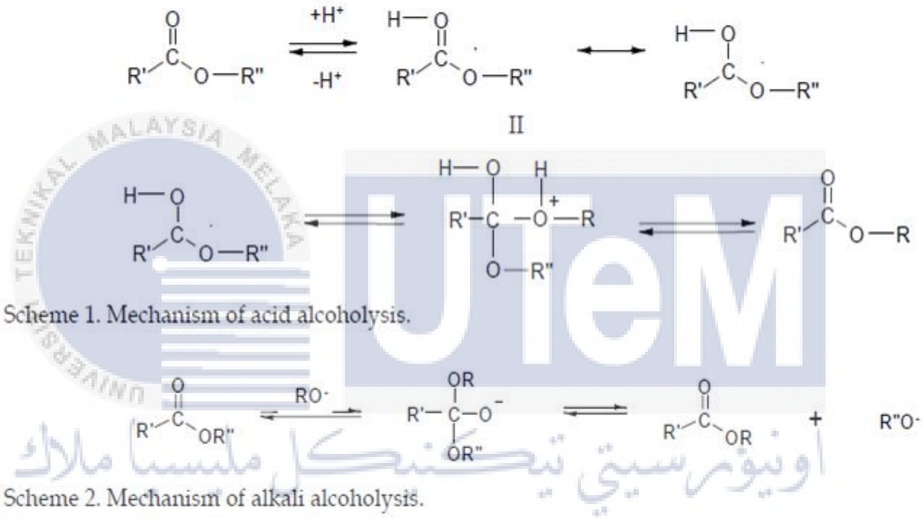


Figure 2-2 ; Mechanism of Alcoholysis

2.4 Reclamation Process

The oil used can be claimed in many ways to restore its original characteristics. Oil reclamation effectively reduces the level of unwanted molecular species found in service transformer oils, such as sludge, acid, ketones, other polar species and water produced by the aging process. Therefore, reclamation brings substantial benefits not only to utility companies but also to communities in general, thereby reducing combustion of oil and environmental impacts on gas effluents generated by combustion of petroleum derivative. Another important benefit is the demand for lower mineral oil and therefore less use of non-renewable petroleum derivatives. For the final consumer, the economic advantage of this process is considerable, as the cost of regenerated oils is about 30% lower than that of the new product, while the quality is similar [2], [3]. Reclamation of insulating oils by means of adsorbent beds has been widely implemented for almost 30 years. In practice, there are two types of operation modes for the reclamation process, as shown in Figure 2-3 [1].

Figure 2-3 : Online Mobile Insulating Oil Reclamation Plant: (left) Mobile Truck; (right) Column Tanks Filled with Adsorbent [1]

Some techniques have been carried out by some researchers and some oil regeneration companies. It consists of reclamation through adsorption and filtration type. The explanation below show two types of reclamation process.

2.4.1 Reclamation By Percolation

The oil used is filtered by a layer of granulated sorbent material loaded in vertical cylindrical vessels [20]. The insulating oil is collected from the bottom of the electrical equipment, and heated to a specific temperature. The insulating oil is circulated through a filter in order to eliminate solids and suspended particles, and the oil is delivered back to the top of the electrical equipment. The insulating oil is then circulated through one or more cartridges containing adsorbents such as Fuller’s Earth in order to remove soluble polar contaminants. Lastly, the insulating oil is circulated through a reconditioning device in order to remove moisture and gasses [1].

There are currently two types of percolation techniques are percolation by gravity and percolation by pressure. The latter technique can be further divided into four types are bulk filters, deep bed filtration, throw-away and repackable cartridges, and thermo-siphon bypass [1].

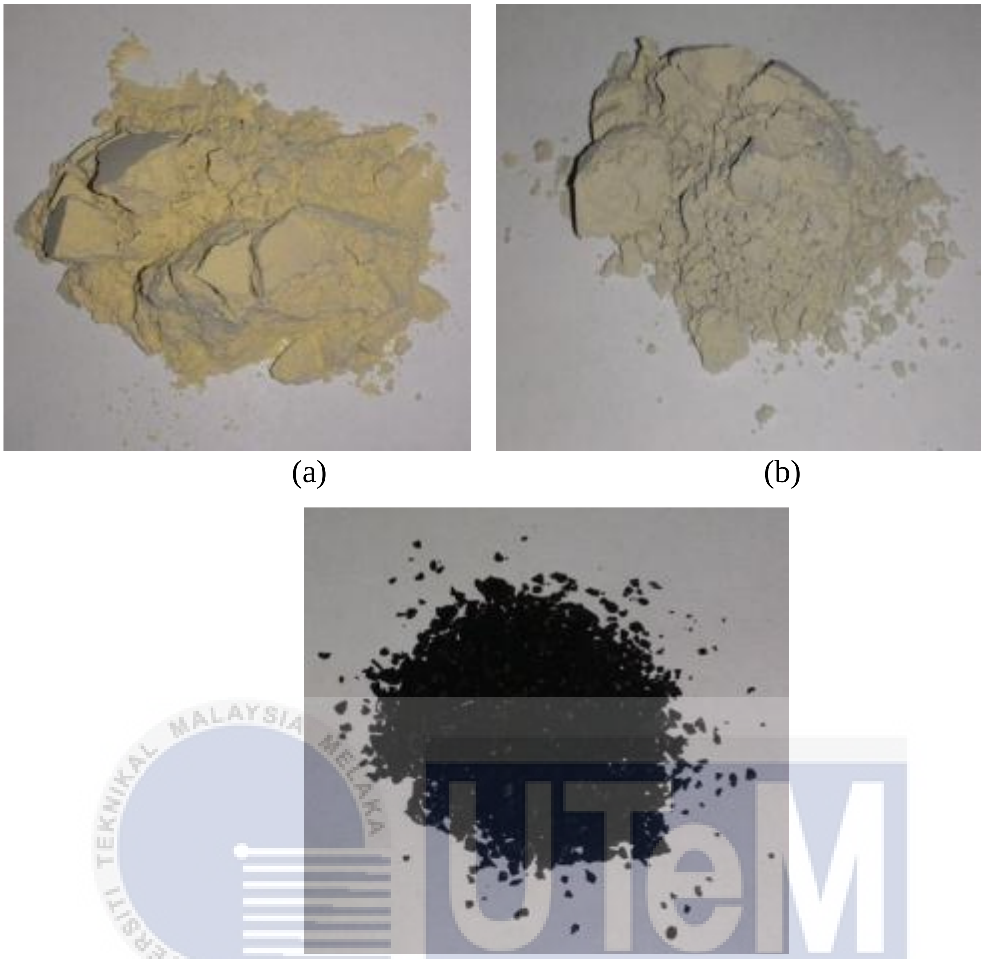
2.4.2 Reclamation By Contact

In this process, the contaminated insulating oil is stirred in a suitable container and Fuller's Earth is used as the adsorbent. This method is impractical for industrial applications since it requires very long outage periods for the electrical equipment. However, this process is useful to recycle large quantities of waste oil. Reclamation by contact is typically conducted on a laboratory scale in order to investigate the feasibility of the reclamation process for given oil as well as estimate the resultant properties of the oil that can be attained if reclamation is conducted on site [1].

A small fraction of the sorbent and heat transfer make the mass absorption of contaminants sufficiently high and cleaned oil passes quickly from the filters. The main disadvantage of the contact cleaning method is the need to dispose of large quantities of contaminated sorbent materials that harm the underground water supply [20].

2.5 Adsorbents for Oil Reclamation

Absorber can be used to remove degradable products including activated earth, silica gel, activated carbon and activated alumina in insulating oils. These adsorbents are used to separate the water content and cycle components in insulating oil for refining and analysis of the insulating oil. There are four types of adsorbents used in the recultivation process are Fuller's Earth, bentonite, activated alumina and activated carbon [1], [2], [4], [7].



(a) (b) (c)

Figure 2-4 :The Adsorbents Used in the Reclamation of Used by Transformer Oils : (a) Fuller’s Earth, (b) Bentonite and (c) Palm Shellv Activated Carbon [1]

2.6 Transformer Oil Properties

A good transformer oil acts as a liquid isolator in the transformer and eliminates heat as the transformer 's coolant medium [20]. To make the right choice for electrical insulating oils, it is important to understand their properties and the effects of various factors.

2.6.1 Breakdown Voltage (BdV)

Breakdown voltage resists voltage where the prospect of failure is at a given voltage. In order to achieve the best insulation oil, higher values of breakdown voltage are required. The higher pressure breakdown can prevent the oil from breaking down under electrical stress [19]. It is measured by the application of a voltage between two electrodes under prescribed oil conditions. The dielectric test measures the voltage of the oil, which indicates the amount of contaminant in the oil. For mineral oil, a generally accepted minimum dielectric strength is 30 kV for high- voltage transformers of 230 kV and above and 27 kV for transformers with a high- voltage rating of less than 230 kV. New oil should have a minimum dielectric strength of 35 kV by American Society for Testing and Materials (ASTM) methods of testing [16].

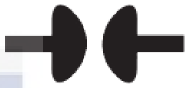
The devices that can be used to measure the breakdown voltage of the transformer oil are Megger OTS60PB, Megger OTS100AF/2, Megger OTS80AF/2 and Megger OTS60AF/2 [21]. The features between these devices are shown in Table 2-2.

Table 2-2 : Features of Megger OTS60PB and Megger OTSAF/2 [21]

	OTS60PB	OTSAF/2
Test Voltage	Max. 60 kV	OTS60AF/2: Max. 60 kV OTS80AF/2: Max. 80 kV OTS100AF/2: Max. 100 kV
Resolution	1 kV	0.1 kV
Operating Temperature	0℃ to 40℃	0℃ to 40℃
Operating Humidity	80% RH at 40℃	80% RH at 40℃

Oil testing specifications, for which the set is pre-programmed, are as follows Table 2-3.

Table 2-3 : Oil testing specifications by Megger OTS60PB [22]

Standard test specification selected	EN 60156 AS 1767 BS 5730 1EC 156 IP 295 NFC 27 SABS 555 UNE 21	ASTM D1816	ASTM D887	CEI 10-1 IOCT 6581 VDE 0370 STAS 286 AS 1767
Electrode shape				
Electrode spacing	2.5 mm	2.0 mm	2.54mm	2.5mm

2.6.2 Moisture Content

The main sole of oil in the transformer is to which provide electrical insulation. When the moisture properties increase, the oil properties are reduced, which affects the breakdown voltage. At the same time, the oil properties are important if the temperature changes where the transformer is cooled and oil is produced [19]. Humidity in oil is measured in parts per million(ppm) by the moisture weight divided by the oil weight. Water can be dissolved in oil as very small droplets mixed with oil or in a free state at the bottom of the oil tank.[16].

2.6.3 Ultraviolet-Visible (UV-Vis)

Faults in the transformer cause the transformer oil to decompose chemically. The transformer oil slumped due to aggregate aging process such as partial discharge (PD), electrical completion and heat aging. This affects the different aging processes and transformer insulation oil pollution [25]. The UV spectrophotometer and Fourier Transform Infrared (FTIR) spectrum have the potential to quantitatively and qualitatively analyze the oil based on the light absorption by the transformer oil. [23]-[25].

The schematic setting of the UV spectrophotometer is shown in Figure 2-5 showing the diffraction of the UV light into the reference cell, the sample cell and the UV spectrum recording. The light is divided in two beams before the sample is reached. The reference is a beam and the other beam passes through the sample. The reference beam intensity is taken as 100% transmission and the measuring ratio of the two beam intensities is displayed.

A testing specimen of mineral insulating oil is placed in a 10-mm path length glass cuvette, which is installed in an UV-Vis scanning spectrophotometer. The instrument is first zeroed with spectral grade heptane. The absorbance curve of oil is then recorded from 360 to 600nm. Intergration of the area under this curve indicates the numeric value of the dissolved decay products in the oil sample. Because of the height sensitivity of spectral analysis, the deterioration of oil purity can be assesessed in the early stages of the decay process.

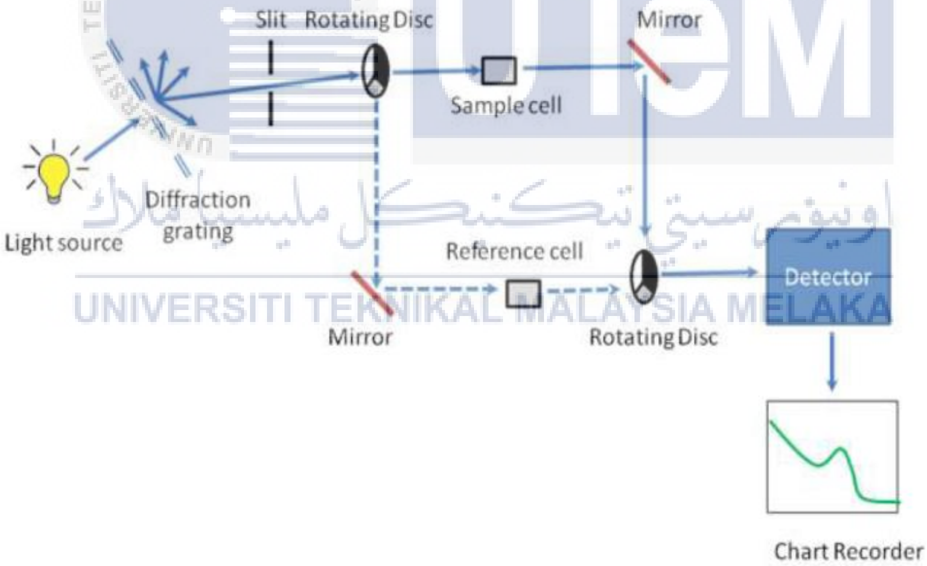


Figure 2-5 : Schematic setup of UV spectrophotometer

2.6.4 Total Acidity Number (TAN)

The amount of sodium hydroxide (NaOH) in one gram of oil to neutralize the acid. The acid content of the oil is indicative. In service- aged oils, the presence of contaminants such as sludge is also indicative. It should be recognized that the acidity test alone determines the conditions under which sludge can form but does not necessarily indicate that actual sludge exits. New transformer oils contain practically no acids. The acid test measures the content of oxidized acids [16].

2.7 Summary

Process improving the characteristics of waste cooking oil methyl ester to get the characteristics same as or almost same as new transformer oil is important especially, the selection of adsorbents and also the filtration technique. Based on previous research, Fuller's earth is a great adsorbent to be used in the reclamation process, as the dissolved decay rate of the product is gradually decreasing. The test was conducted to confirm the decision using a specific parameter of the optimum reclamation process and indeed there was a significant increase in the mean AC breakdown voltage, total acid number, moisture and visible and ultraviolet (UV-vis) for the reclaimed transformer oil compared with those for the used transformer oil.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section discusses the system flow overall for this project. Furthermore, the flowchart of this project will be utilized as a guideline to lead the investigation of the projects to overcome the outcome. This part likewise will discuss about the method that suitable to be utilized as a part of the project to conduct experiments about how temperature, speed string and absorbent can affect the properties of transformer insulating oil. Hence, the outcome and information acquired will be analyzed and the properties of waste cooking oil methyl ester (WCOME) oil will be tested to see the limitation

3.2 Flowchart of Methodology

For this project, there are several steps that have been used to get the results of optimization waste cooking oil methyl ester (WCOME) electrical characteristic by reclamation process. The flow chart is a divisive representation of the steps that must be followed in carrying out this project. All the processes in this project will be explained more easily through the flow chart, Figure 3-1 : Flowchart of Transesterification and Figure 3-2 : Flowchart of Reclamation shows the process of projects.

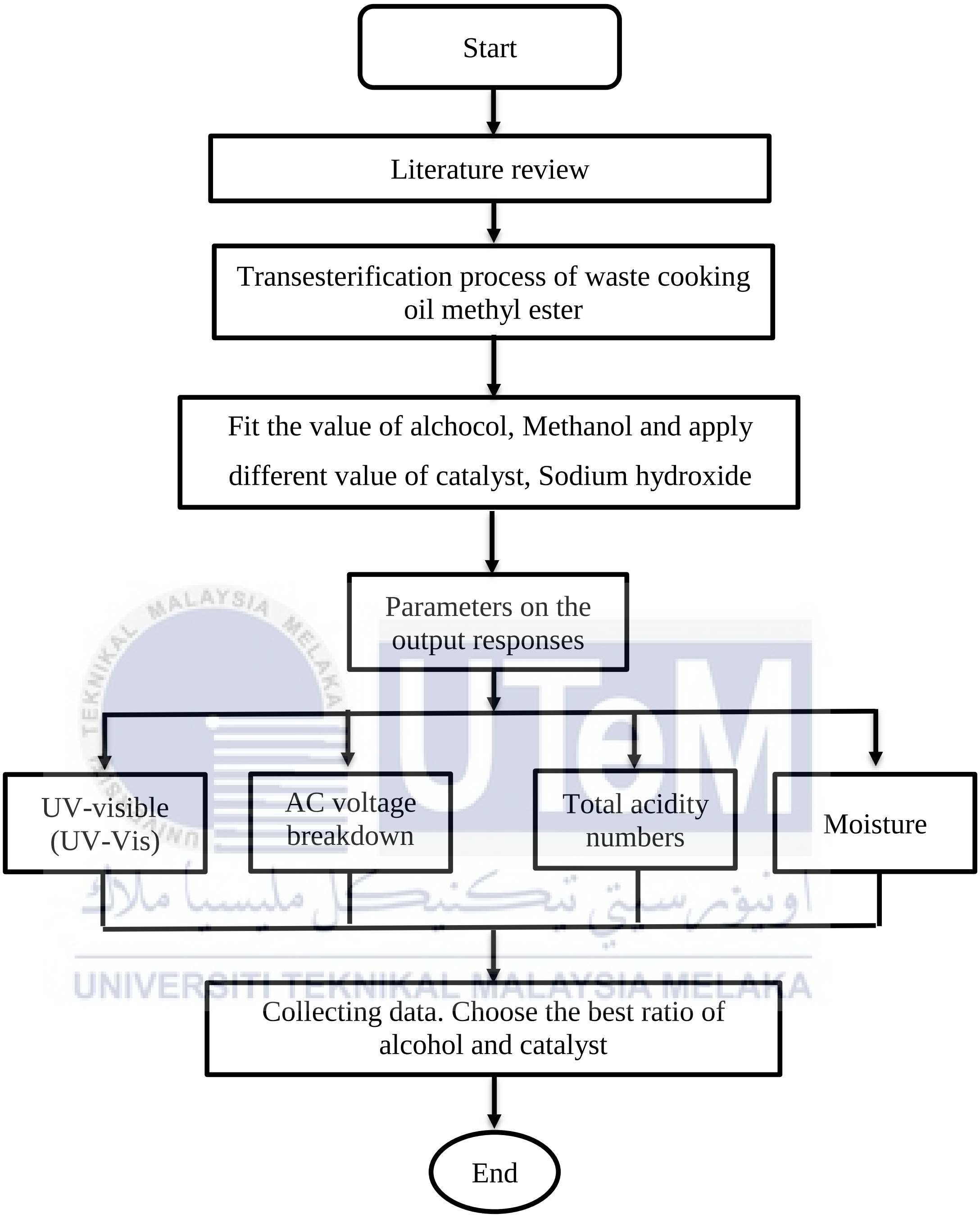


Figure 3-1 : Flowchart of Transesterification

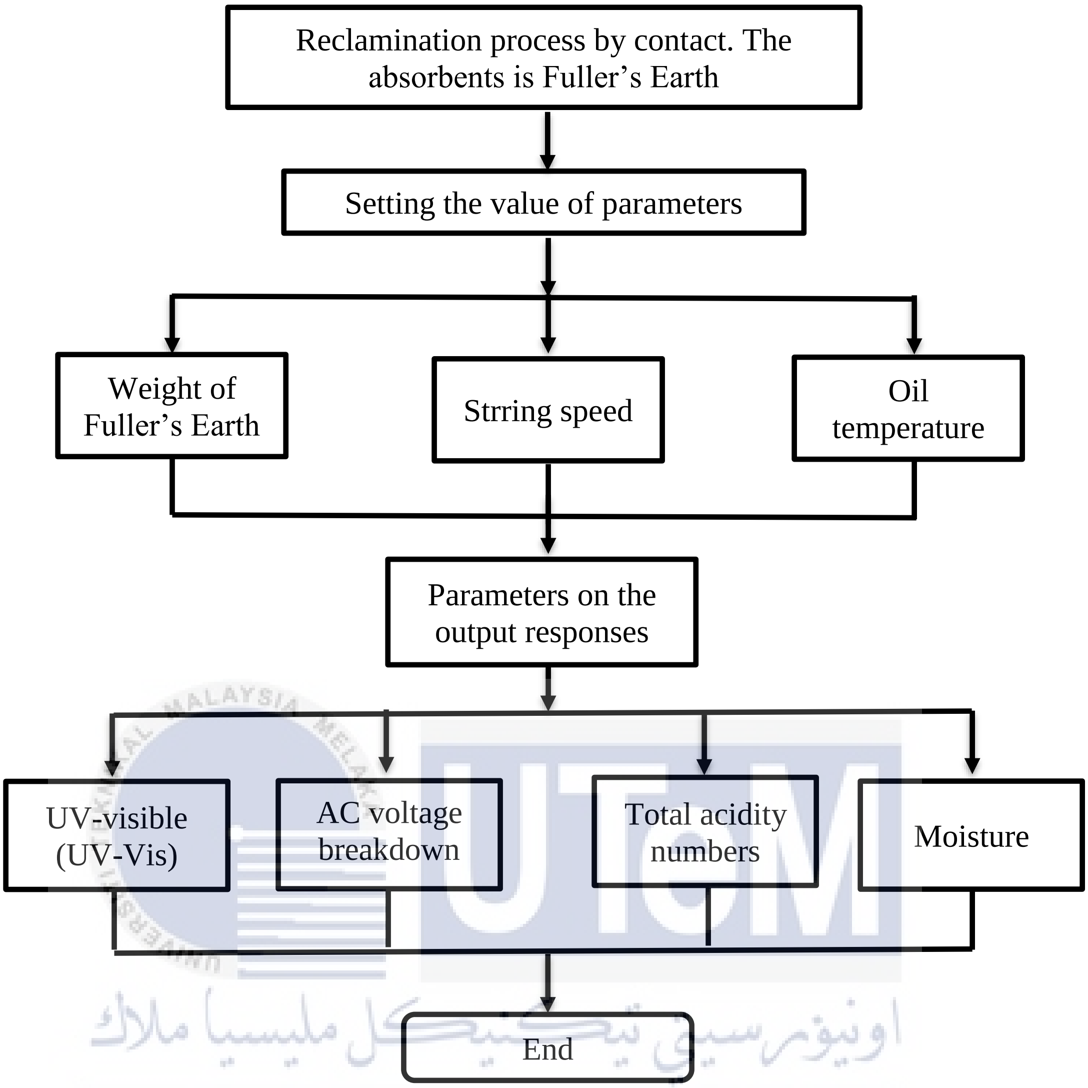


Figure 3-2 : Flowchart of Reclamation

3.3 Experiment Review

The purpose of this step is to prepare a sample of transesterification oil to be used for breakdown voltage test, ultraviolet-visible , total acid number test and moisture effect test. Next, Oil reclamation was processed where all the contaminants in used transformer oil are removed by using an agent also refer as adsorbent. The reclamation process parameters used in this study are weight of the Fuller's earth adsorbent, stirring speed used to mix the used transformer oils with the adsorbent, and temperature of the used transformer oils when they are mixed with the adsorbent. The parameters in order to maximize the AC breakdown voltage (BdV), and minimize the total acid number (TAN), moisture and ultraviolet-visible (UV-Vis) of the reclaimed transformer oils. The details theoretical and information for this part already mentioned in Chapter 2.

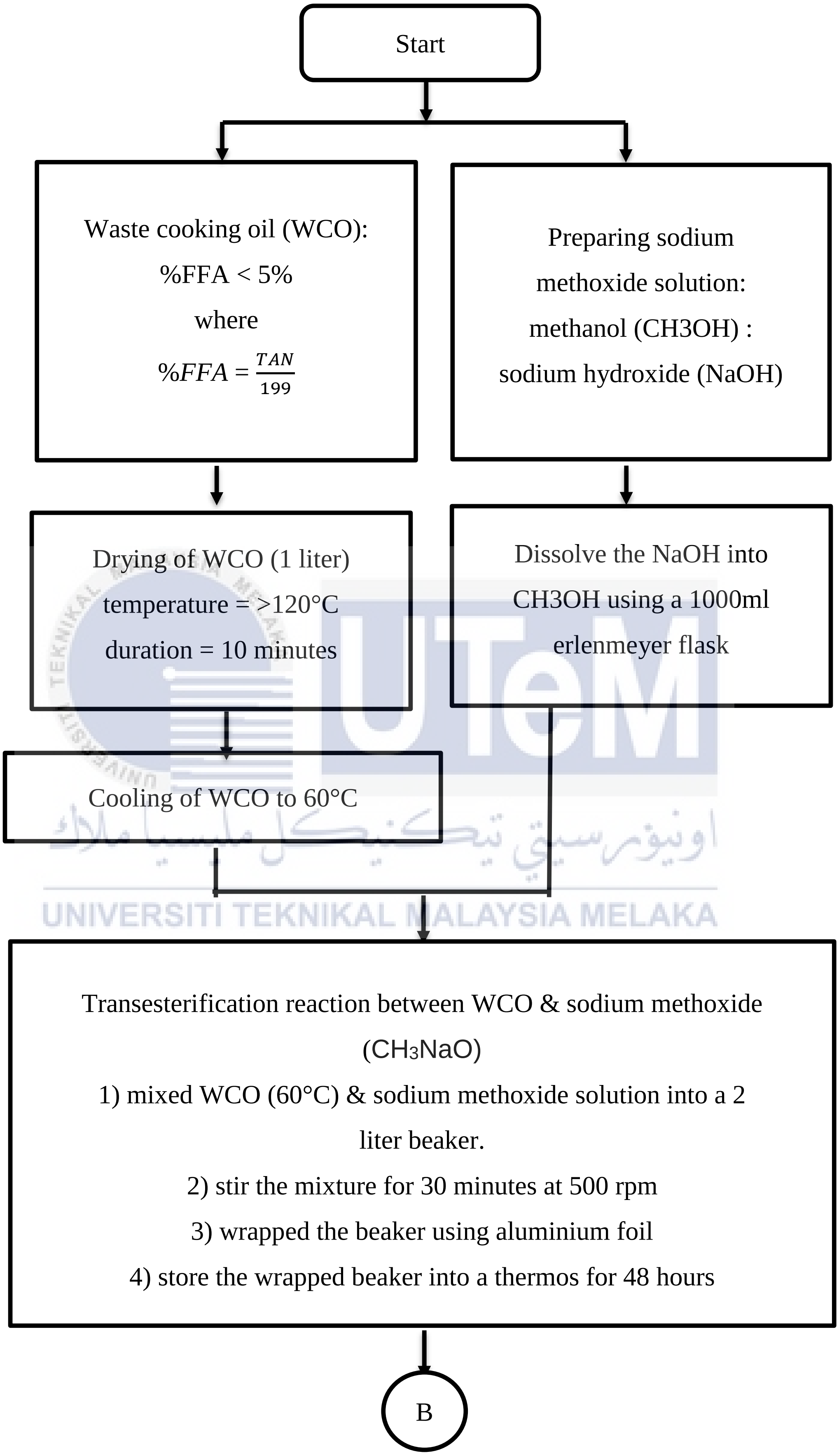
3.4 Transesterification Process of Waste Cooking Oil Methyl Ester

For this project, the sample used was waste cooking methyl ester (WCOME). The cooking oil had been used for frying process. This sample was used for the whole experiment in Final Year Project (FYP). Figure 3-3 shows the sequences of the transesterification of waste cooking oil methyl ester.

The study are carried out using methanol and sodium hydroxide (NaOH) as catalyst to determine whether different catalyst quantities affect the transesterification rates.

Table 3-1 : The value of Methanol and Sodium hydroxide, NaOH

Test	Methanol	Sodium hydroxide, NaOH
1	250 ml	5 g
2	250 ml	7 g
3	250 ml	10 g


Start
Waste cooking oil (WCO):
%FFA < 5%
where
$\%FFA = \frac{TAN}{199}$
Preparing sodium methoxide solution:
methanol (CH3OH) :
sodium hydroxide (NaOH)
Drying of WCO (1 liter)
temperature = >120°C
duration = 10 minutes
Dissolve the NaOH into CH3OH using a 1000ml erlenmeyer flask
Cooling of WCO to 60°C
Transesterification reaction between WCO & sodium methoxide (CH_3NaO)
1) mixed WCO (60°C) & sodium methoxide solution into a 2 liter beaker.
2) stir the mixture for 30 minutes at 500 rpm
3) wrapped the beaker using aluminium foil
4) store the wrapped beaker into a thermos for 48 hours
B

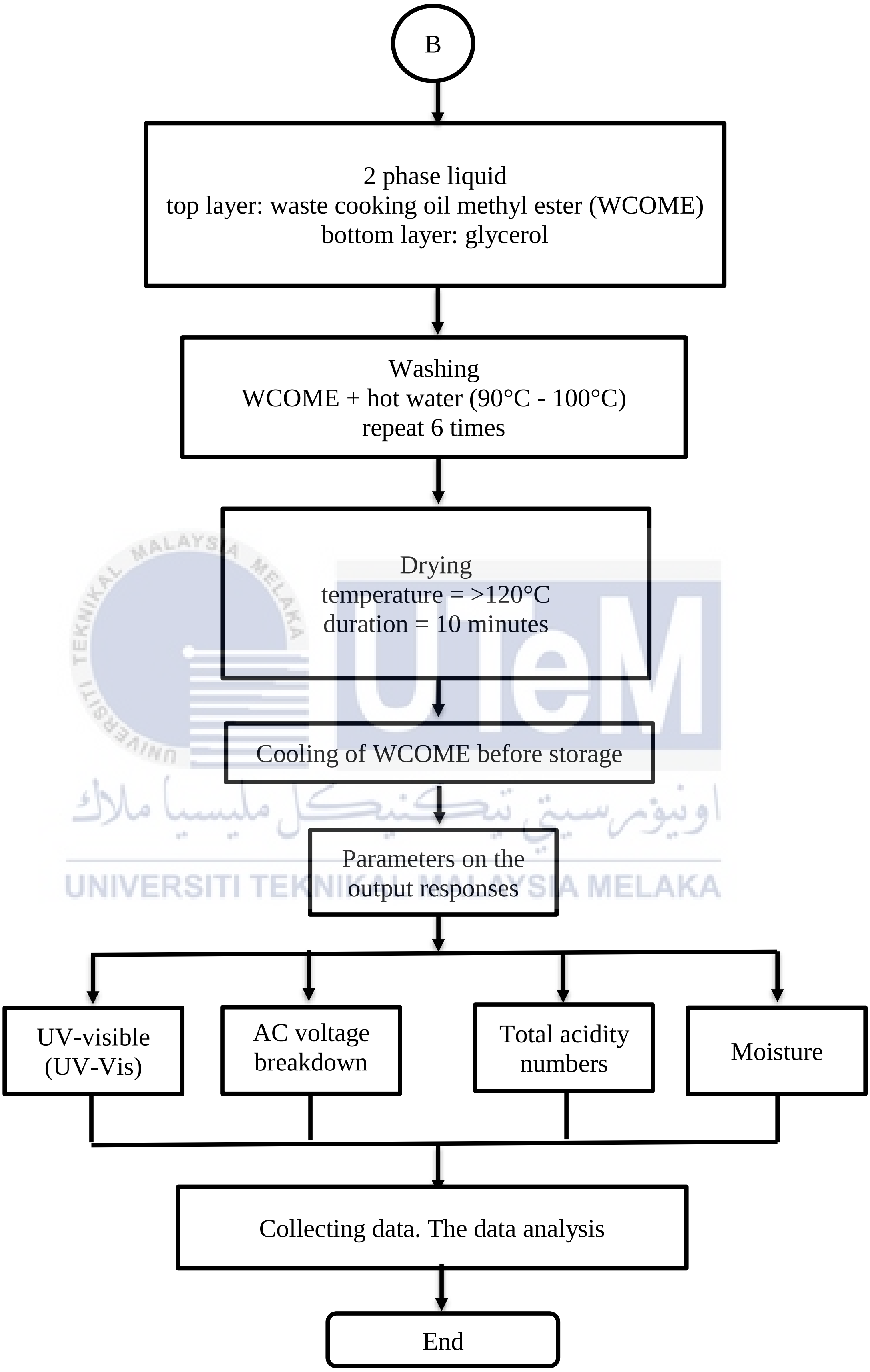
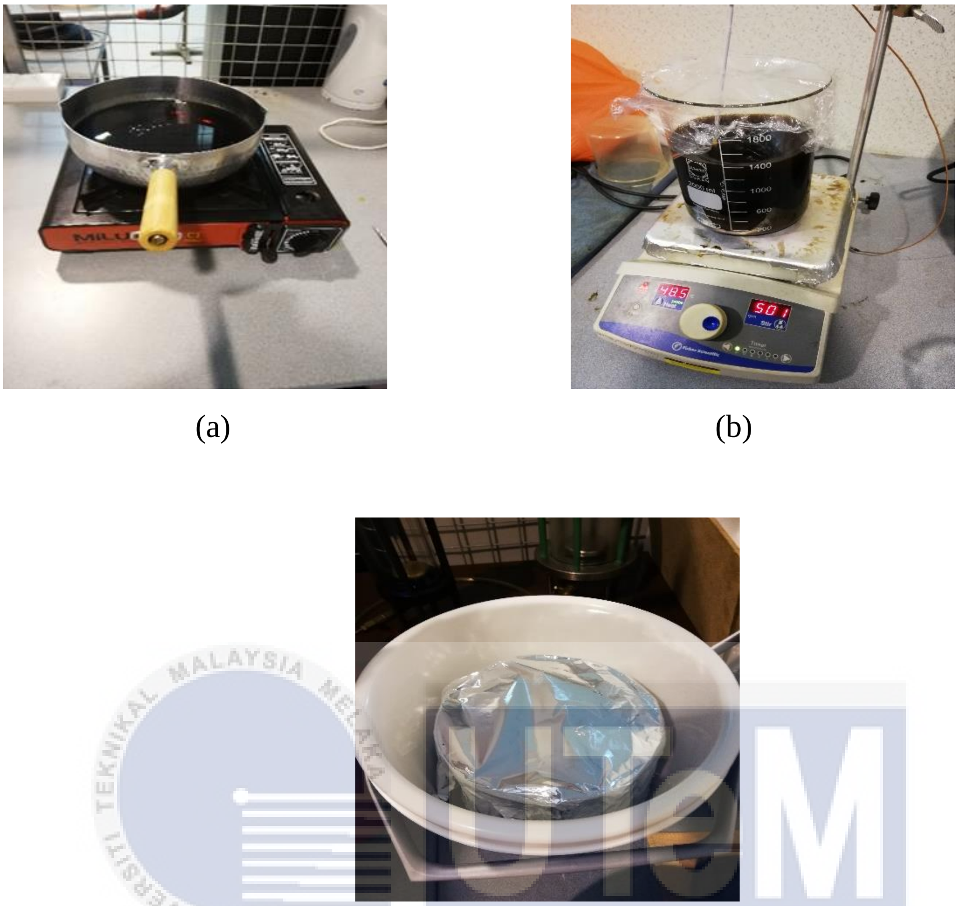


Figure 3-3 : Flowchart of Transesterification Step Process



(a) (b)

Figure 3-4 : Transesterification Process : (a) Drying of WCOME, (b) Mixed WCOME & CH3NaO solution (c) Store the Wrapped Beaker of WCOME

3.5 Reclamation Process of Waste Cooking Oil Methyl Ester

For this project, the sample used is waste cooking oil methyl ester. The cooking oil had been used for frying process. This sample was used for the whole experiment in Final Year Project (FYP). Figure 3-5 shows the sequences of the transesterification of waste cooking oil methyl ester

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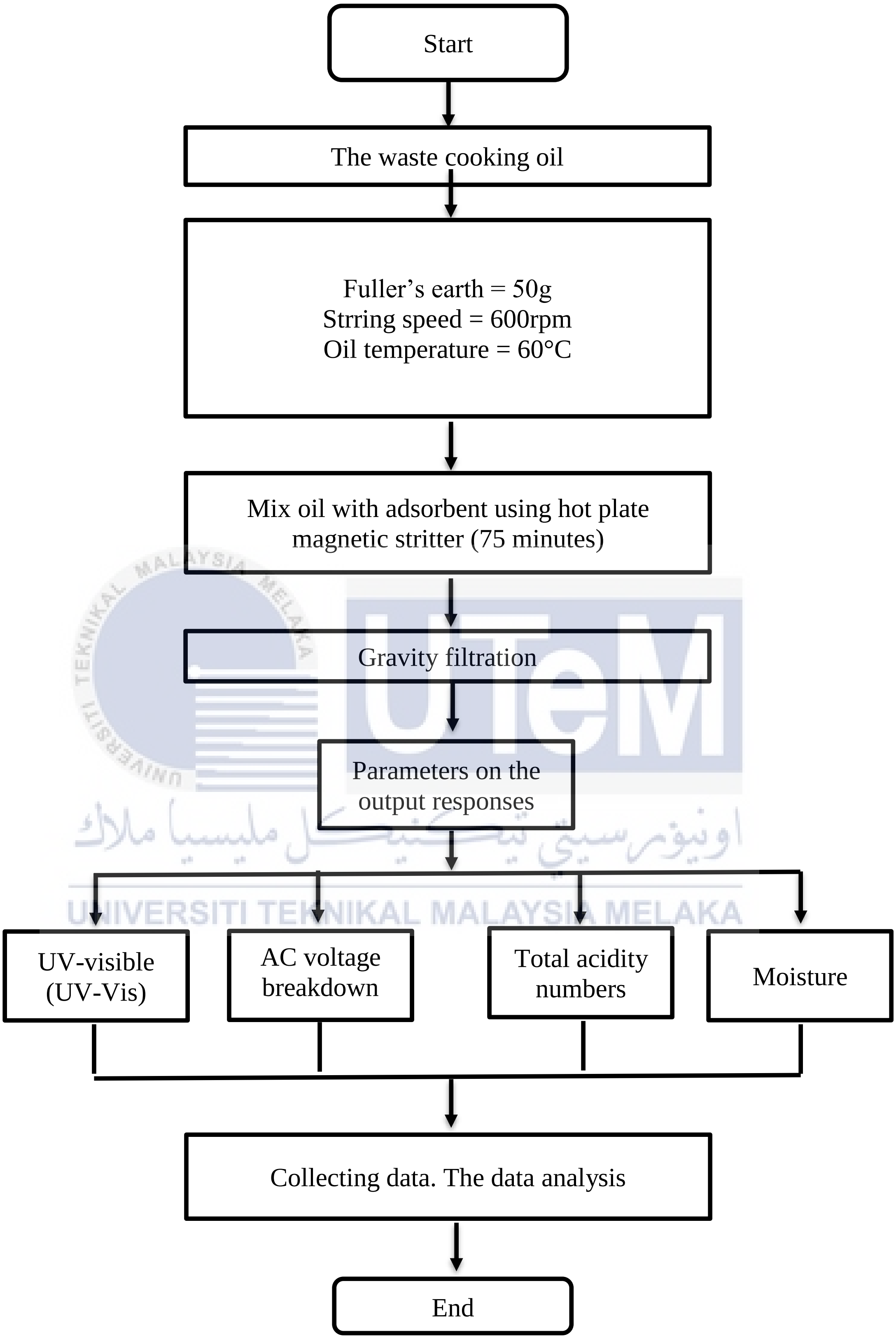
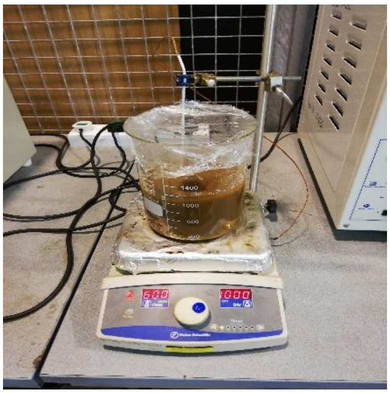
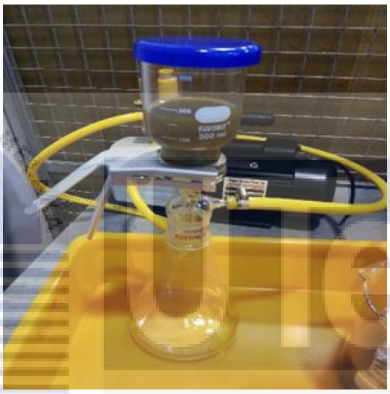


Figure 3-5 : Flowchart of Reclamation Process

(a)



(b)



(c)

Figure 3-6 : : Reclamination Process : (a) Weight of Fuller Earth, (b) Strring of WCOME & Fuller Earth (c) Filteration of the mixer

3.6 The Sequence process for improvement of Waste Cooking Oil Methyl Ester

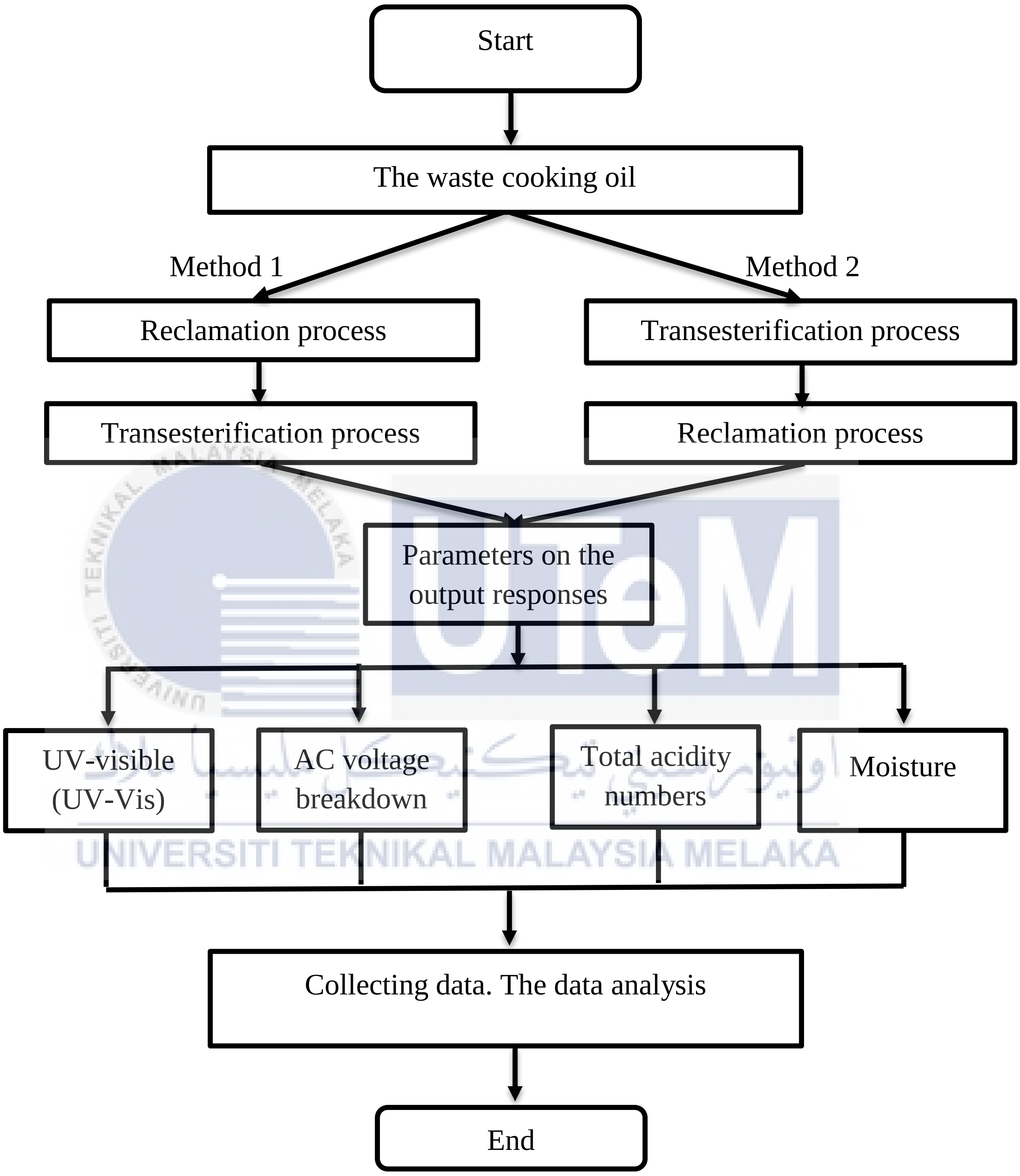


Figure 3-7 : Flowchart of difference sequence of reclamation process

3.8 Testing Oil Properties

In this section, there are four test will be conducted. The first test is AC breakdown voltage which is to determine the voltage that the oil can withstand, the second test is total acid number test which is to determine the number of acid in the oil and the moisture to trace the presence of a liquid especially water, often in trace amounts. Lastly, test is to discover ultraviolet-visible in the oil. All this test will be conducted to know the validation and justify the performance of reclamation oil produced.

3.8.1 AC Breakdown Voltage (BdV)

BdV measurement is set up according to standard ASTM D1816 standard [31]. Using Megger OTS60PB portable oil test to measure AC breakdown voltage of reclaim oil. This test conducted under room temperature 24ºC . Megger OTS60PB has two electrodes which breakdown voltage will occur. The value of oil for testing is 500ml. Each sample will be tested up to 5 breakdown voltage testers. All the data will be recorded and analyzed after finish the experiment. The procedure to conduct BDV test is as follows:

i) This test is conducted if the water content of the WCOME is less than 200ppm. The sample should be poured into the vessel, up to the 500 ml level mark. Avoid the formation of air bubbles in the oil as it affects the project and ensure that the temperature of the oil is at room temperature (24ºC) as in Figure 3-8.

Figure 3-8 : Measure the temperature of the WCOME sample

ii) The gap between the electrodes shape A is set to 1mm as in Figure 3-9. Next, the oil sample is placed in the test chamber as in Figure 3-10.

Figure 3-9 : 1mm gap of Megger OTS60PB

Figure 3-10 : The oil placed in the test chamber

iii) After the chamber cover is closed, the Meggar OTS60PB is switched on. Then, the ASTM D1816 standard is selected from the main menu (refer Figure 3-11) and The test vessel's oil sample is now readily available for dielectric strength tests.

iv) 4. The process in step 3 is repeated to get 5 data of BDV test for each sample. Large sample of data is required for better accuracy.

Figure 3-11 : Select ASTM D1816 standard

3.8.2 Total Acidiy Number (TAN)

This method used is to measure acidity in waste cooking methyl ester oil (WCOME). This method will follow accordingly with ASTM D974 standard [32]. Procedure to conduct TAN Test :

i) Calibrate the electrode with buffer solution

Figure 3-12 : Calibration process

ii) Standardization by weight around 0.1g of Potassium Hydrogen Phthalate (KHP) into beaker, add approximately 80mL of DL water, titrate with NaOH in IPA 0.1 mol/L.

iii) Duplicate the blank titration.

iv) Weight 5g of sample into titration vessel. Add 20mL IPA solvent.

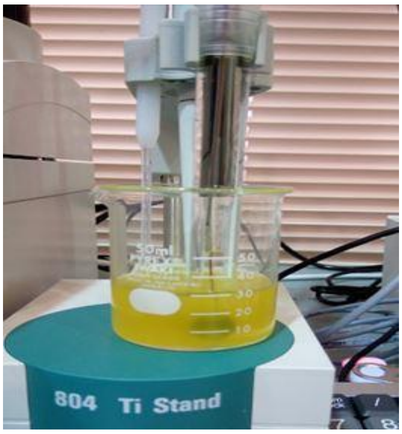


Figure 3-13 : Titrate the sample with fresh 20mL IPA

v) Titrate with NaOH in lPA until pH 11.5. After finishing the blank titration step, choose TAN method.

Figure 3-14 : After finishing the blank titration step, choose TAN method

vi) TAN result show at screen.

3.8.4 Moisture Test

This method used is to measure water present in an insulating liquid by using Karl Fischer titration according to ASTM D1533 standard. Procedure to measure moisture :

i) Insert the oil into the syringe and make no bubble produce in the syringe

ii) The syringe will be weighed first to know the mass of the oil used in the moisture content experiment.

iii) After the method is loaded, the [START] button is pressed to start conditioning. Wait for a while until the screen display “Conditioning OK”.

iv) Make sure the oil didn’t have contact with the beaker during adding the sample.

Figure 3-15 : Add the sample into the space provided

v) Take again the weight of the sample used and insert it into the KFC.

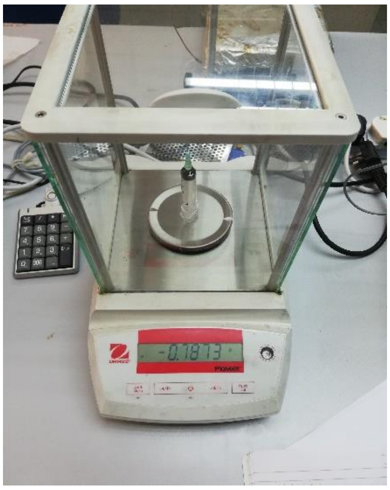


Figure 3-16 : Weight the sample

vi) Wait for the KFC showed the value of moisture.

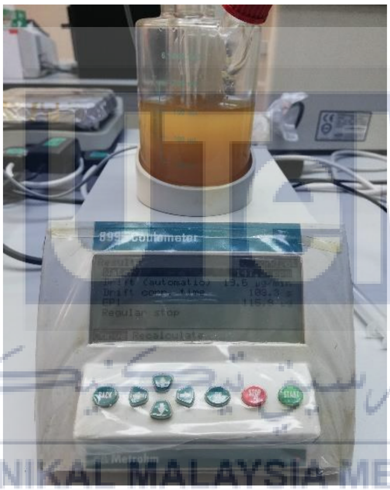


Figure 3-17 : Results dialog on the screen of KFC

vii) Repeat the test again to sample each oil.

3.8.6 Ultraviolet-Visible (UV-Vis) Test

Uv-vis measurement by UV spectrophotometer. this experiment Shimadzu corporation UV-1800 PC is used for analyzing the transformer oil which is shown in the Figure 3-18 by using D6802-02(2010) standard.

Figure 3-18 : Shimadzu corporation UV-1800 PC

Procedure to measure ultraviolet-visible (uv-vis) :

i) Fill one glass cuvette with heptane, place it in the sample holder and zero the instrument by adjusting it to read zero absorbance.

ii) Move the heptane filled cuvette by placing it to the reference position.

iii) Fill the second glass cuvette with the oil specimen and place it into the sample holder.

iv) Set the instrument to scan the region from 360 to 600 nm and begin scanning the specimen.

v) Display the absorbance curve and set the instrument to calculate the area under the curve.

3.9 Project Milestone

There are seven milestones in this project. It is important to make the Final Year Project (FYP) run smooth and orderly.

Milestone 1: Get the topic

This is the first step that every student needs to have a topic that will be their experiment for the Final Year Project (FYP).

Milestone 2: Find references

This is the most important time before starting any experiment. Using journal, IEEE papers or have the discussion with the supervisor will help to ensure the student do it in a proper way.

Milestone 3: Literature Review

This milestone is to study about the concept of transformer insulating oil and how temperature can influence the transformer oil properties. Besides that, all properties of the oil and all types of test that need to conduct will be explored in this milestone.

Milestone 4: Transesterification process to check the oil properties

This is where the experiment begins. All the oil properties will be tested for their original properties before the next semester experiment. The properties that need to be checked are breakdown voltage (BdV), total acid number (TAN), ultraviolet-visible (uv-vis) and moisture.

Milestone 5: Reclamation process to check the oil properties

This milestone will be conducted on the next semester. At this point, each oil will be tested at a various parameter which is Fuller’s earth, stirring speed and oil temperature. All the data will be collected and analyze to see whether temperature will influence the oil properties or not.

Milestone 6: Record and data collection

During the experiment, the characteristic changing will be observed and the data will be collected for the analysis.

Milestone 7: Result Analysis

Analyze all the data that's been recorded during the experiment.

Milestone 8: Report Writing

This report will contain an introduction from Chapter 1 until Chapter 5 which is the conclusion for the overall Final Year Project (FYP) process including the references.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

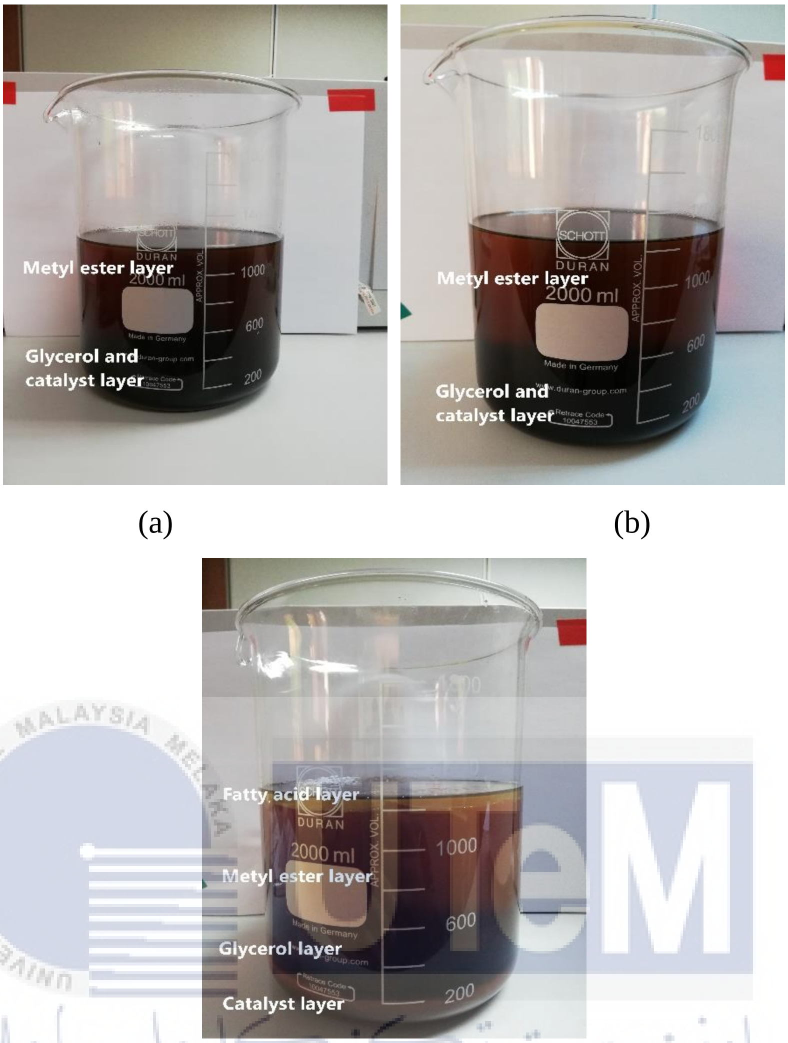
In this chapter, the result will be discuss based on review of previous study. There are several studies that have conduct researches on transformer oil characteristic, reclamation process and transesterification process.

4.2 The Influences of Catalyst for Transesterification Process

The transesterification process using different ratio of methanol and sodium hydroxide (NaOH) as acid base. Transesterification is a triglyceride reaction with an alcohol, usually methanol, in the presence of an acidic or alkaline catalyst to produce esters of fatty acids and glycerol [12]. The reaction was carried out to separate the glycerol from the ester within a 48 hours period. Separation of the two phases and removal of excess solvent in each phase gave biodiesel and glycerol with good yield. During the purification process, methyl ester was washed with water to remove the catalyst, residual amount of glycerol and methanol.

4.2.1 Physical Change of Oil Samples

Application of alkali catalyzed transesterification reaction provide faster rate, nearly 4000 times faster than that catalyzed by the same amount of an acid catalyst [34]. Figure 4.1 shows the result obtained from the mixer of sodium hydroxide (NaOH), methanol and waste cooking oil (WCO) reaction after 48 hours.



(a) (b)

(c)

Figure 4-1 : (a) WCO + 5g NaOH (b) WCO + 7g NaOH (c) WCO + 10g NaOH before bleaching process

The catalyst works to accelerate the process of transesterification. Through the results, the certain amount of acid base (NaOH) affect the process. For WCO + 5g and WCO + 7g of NaOH only able to produce catalyst layer, glycerol layer and methyl ester layer. Fatty acid layer can be produced by 10g NaOH mixer. Referring to the theory transesterification, it will produce esters of fatty acids and glycerol. It is noted WCO + 10g NaOH achieve the theory concepts within 48 hours. That shows the influence of NaOH concentration on the evolution of ester yields with time.These processes could effectively convert waste cooking oil containing high amount of FFAs ranging from 3% to 40%.[34]. The methyl esters layer obtained is washed times using warm water to remove methanol and glycerol. Figure below shows colour of waste cooking methyl ester. The changing of colour from dark to light indicates that the catalyst enhancement accelerates the process of transesterification complete are shown in Figure 4.2. The 5g of NaOH little dark because fail to separate between esters of fatty acids and glycerol.

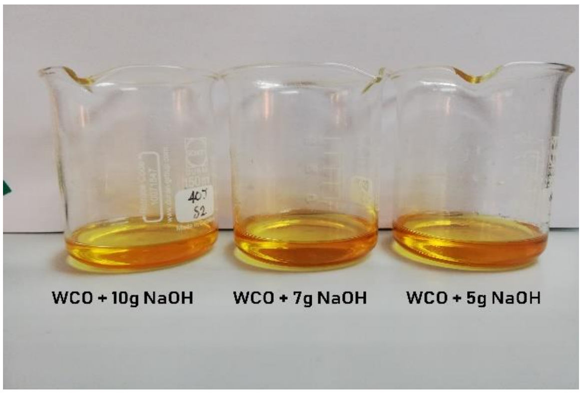


Figure 4-2 : Colour of waste cooking methyl ester after bleaching process

From this process, it can be concluded that catalyst affects the transesterification in the waste cooking oil to produce esters of fatty acids and glycerol. The process of transesterification helps to improve the content in the waste cooking oil hence it has high possibility to be used as an insulation liquid inside a transformer.

4.2.2 Moisture Test

The effect of water content in the methanol on the transesterification reaction was tested in Figure 4.3. The reaction could still proceed satisfactorily because all the tests recorded a good improvement from pure waste cooking oil (WCO). The confirmation of this point is important as this means extensive purification/drying of the recovered methanol is not necessary, hence cutting down the process cost.

It is shows WCO + 5g NaOH recorded the highest moisture at 319.98ppm, while WCO + 7g NaOH recorded the lowest moisture, 200.78ppm in Figure 4-3. That results achieved did not indicate significant differences between others. All the readings he noted were a good decline of 1036.5 ppm. The increase of water vapor in insulation liquid may not only reduce its dielectric strength but also changes the partial electrical field distribution which then will cause in discharge or breakdown of insulation. Hydrolysis of fatty acid methyl ester (FAME) was a function of water content, and the percentage of remaining methyl decreased with increasing water content [37]. Due to the non-uniform drying time, 5 g NaOH records the second highest value. The bleaching process should also be considered because it affects the moisture content in methanol purification.

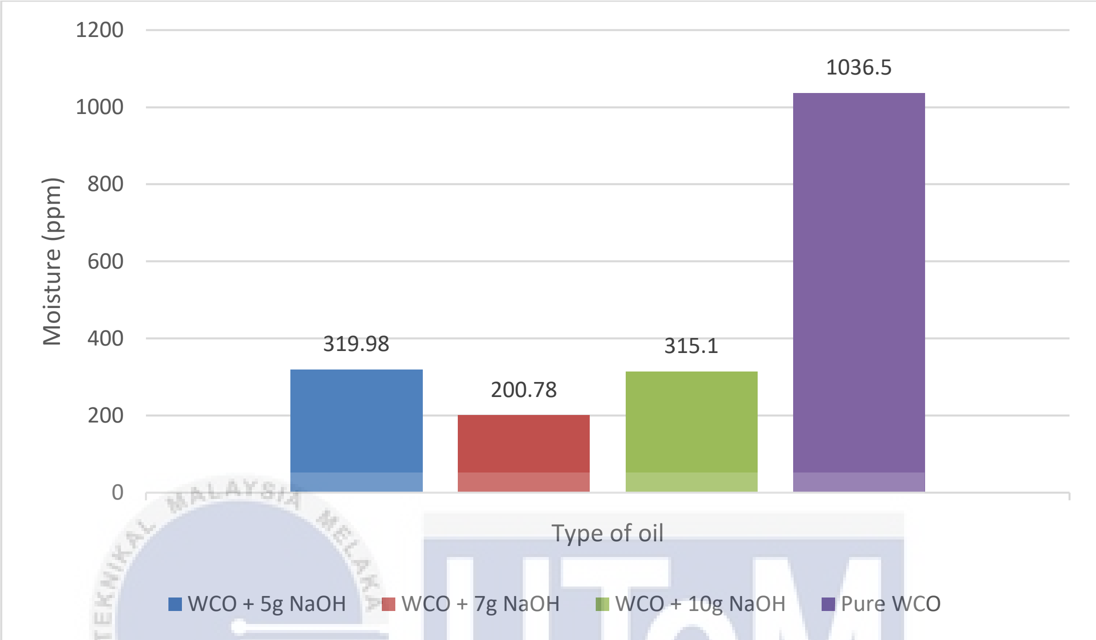


Figure 4-3 : The reading of moisture test for different catalyst (NaOH)

From this process, it can be concluded that catalyst amount does not affect the reduction of oil moisture. As the water content's requirement as per IEEE C57.147 is should be less than or equal to 200 ppm, it is notice that only ratio WCO + 7g NaOH most close fulfilled the water content limits for NaOH catalyst. WCO + NaOH need to treatment for improving oil characteristics.

4.2.3 Breakdown Voltage Test

Breakdown voltage (BdV) of insulation liquids is one of the experimental testing to designate of the contaminant like a water and solid suspended matter. Water or moisture content is the factor will be affect the electrical strength of the insulating oil.

The Figure 4-4 shows that the higher Bdv is WCO + 7g NaOH that recorded 9.8kV. WCO + 10g NaOH oils fail to record a any increase, which remains the same as the waste cooking oil at 7kV. Referring to earlier discussion of moisture, it was mentioned that WCO + 7 g NaOH is the lowest by recording the highest value of the

BdV. Water content is also influenced by a bleaching step and methanol hydrolysis. The methyl esters layer obtained is washed three times using warm water of 50-55°C to remove methanol and glycerol before dried.

Accordingly, the characteristics are likely to decline with increase in the water content. In the relationship between the water content and the breakdown voltage, the water content increases and the breakdown voltage is likely to decrease. According to IEEE C57. 147, the acceptable BdV of new natural ester fluids is should be more than or equal to 20 kV. WCO + NaOH need to treatment for improving oil characteristics.

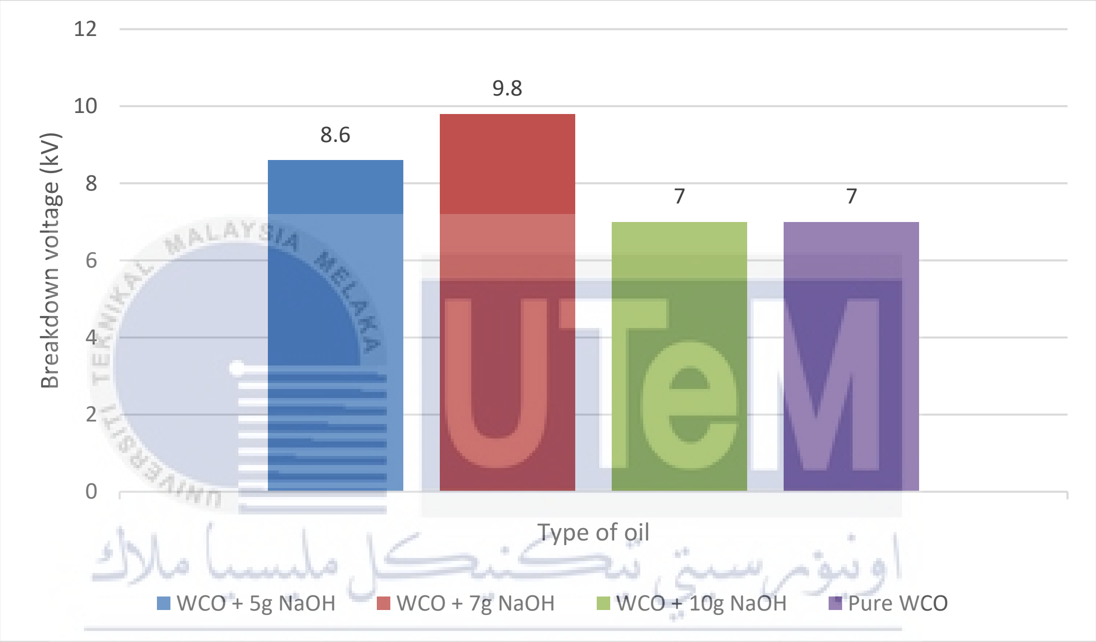


Figure 4-4: The result of breakdown voltage (BdV) by different value of catalyst for transesterification process

4.2.4 Total Acidty Number Test

Increased oil acidity causes the oil resistivity to decrease. It also increases the oil dissipation factor. Excessive oxidation accelerates oil slug formation rates. It may also cause the paper used for insulation in the transformer windings to deteriorate abnormally [38].

The amount of acidity is closely related to the FFA reading. According to the results of the previous sections, WCO + 10gNaOH most successfully produces fatty acid through the transesterification process are shown in Figure 4-5. For the WCO + 10g NaOH records the lowest acidity at 0.2352mg/KOH. 92% decrease from the waste cooking oil. for WCO + 5g NaOH also note the downward reading at 0.3408mg/KOH.

The percentage of free fatty acid conversion to methyl ester increased and the acid value of oil decreased. overall all the readings he noted was a good decline from 2.7972 mg/KOH.

As a result, all the readings have been successful in recording a decline even though it does not level the transformer oi which is less than 0.03 mg/KOH. Hence, the alcohol molar/oil ratio is a variable that must be always optimized. Nevertheless, a later increase of molar ratio did not result in an increase in the yield, since a lower value is obtained. This was because for higher molar ratios the separation of the glycerol was difficult [10].

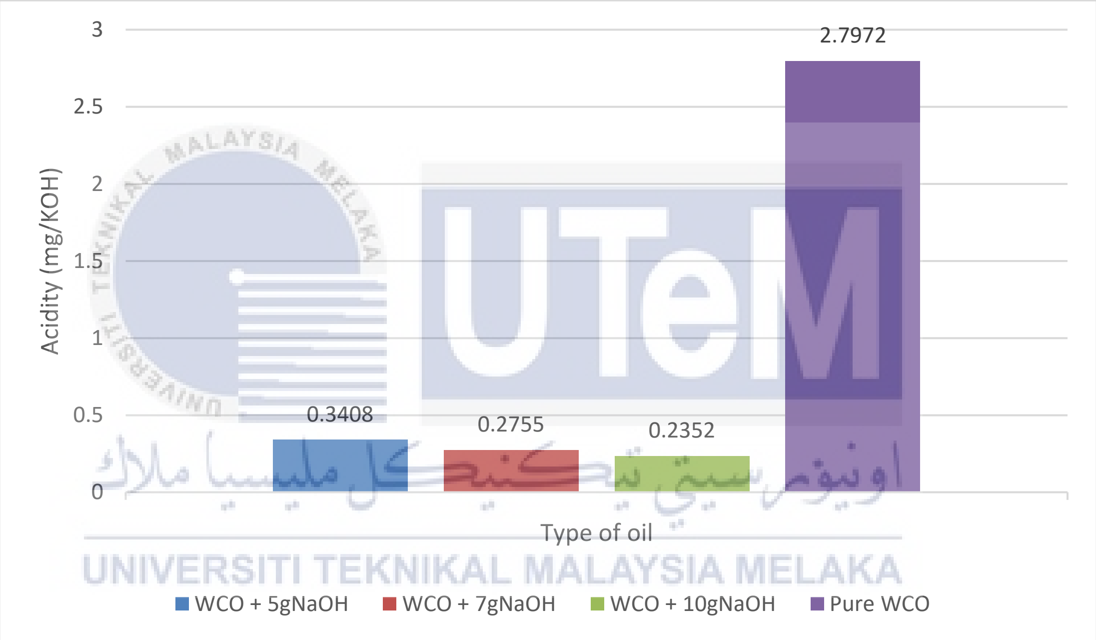


Figure 4-5: The result of acidity by different value of catalyst for transesterification process

4.2.5 Ultraviolet-visible Test

Integration of the area under curve indicates the numeric value of the dissolved decay products in the oil sample. Because of high sensitivity of spectral analysis, the deterioration of oil purity can be assessed in the early stages of the decay process. The transesterification process in biodiesel production is influenced by the content of free fatty acids (FFA). Waste cooking oil which has been analyzed for the content of FFA is adsorbed using uv-vis process.

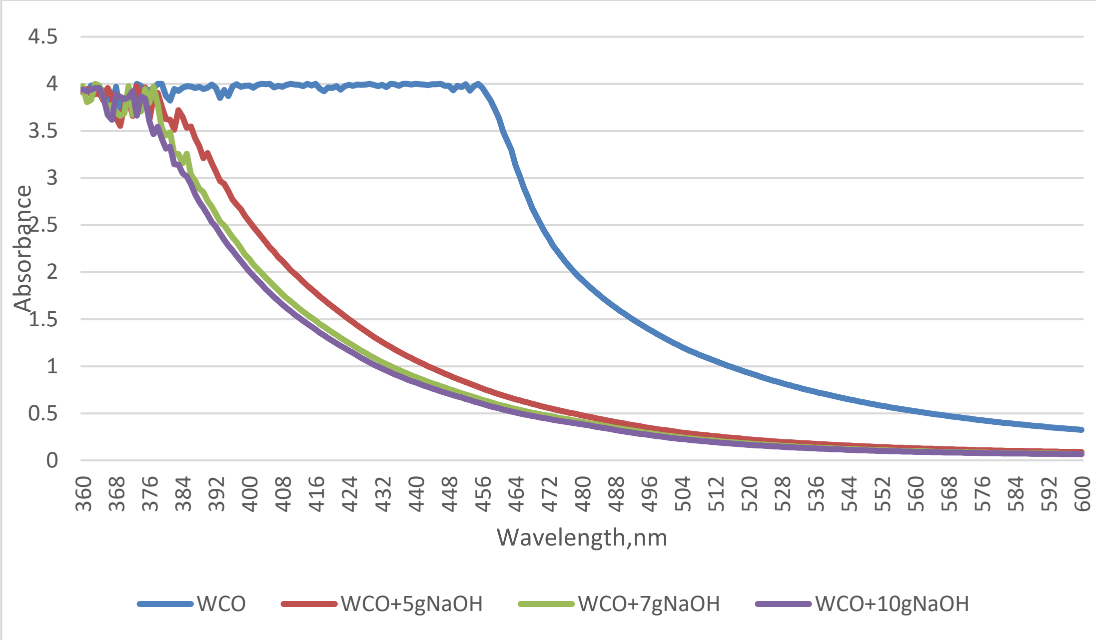


Figure 4-6 : The absorbance in the the visible range of spectrum by different value of catalyst for transesterification process

In the study, the difference in the total number of catalysts, NaOH due to the difference in the total FFA. Table 4-1 presents WCO + 10gKOH showed the lowest area under graph, 333.6695 while WCO + 5gKOH shows the highest reading at 392.186. The ratio was successful with the results of some of the FFA produced shown in the previous sector and FFA is lost during the transesterification process. This shows that more FFA is produced, less absorption is described through the under-curve area. FFA has become a decay or contaminated material in the interpretation of uv-vis analysis. Figure 4-6 shows the higher the value of the catalyst, the lower the reading of absorbance. This means the impurities can be removed for oil improvement by increasing of NaOH.

In conclusion, the transesterification process can reduce oil defecation. This study, the FFA results will affected the quality of the oil. The best quantity for a catalyst mixture must be explored for maximum output for better quality oil. However, if the catalyst used exceeded 0.5 mole kg-1 oil, the reaction mixture solidified from the formation of soap [11].

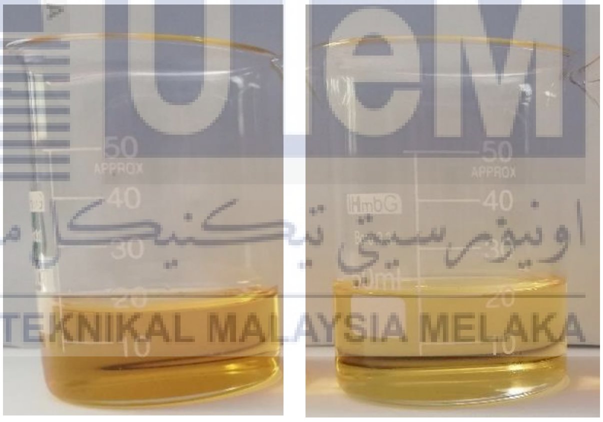
Table 4-1 : Area under the curve for different value of catalyst for transesterification process

Sample	Area under curve
WCO+5gNaOH	392.186
WCO+7gNaOH	348.5345
WCO+10gNaOH	333.6695
WCO	818.88

4.3 Reclamation Process Improves The Quality of Waste Cooking Oil

One way of improving the situation is to reclaim insulating oil by Fuller's earth treatment [2]. Fuller's earth is a clay with the ability to capture contaminants from mineral or vegetable oils and fats. Fuller's earth has become the quality standard in oil regeneration and purification processes. After the transesterification process, the oil through process of reclamation to improve the quality of the oil.

4.3.1 Physical Change of Oil Samples



(a) (b)

Figure 4-7: Colour changing : (a) transesterification, (b) transesterification followed reclamation

Reclamation is used to treat high acidity and sludge isolating oils. Process transesterification follow by reclamation is clearer than transesterification only. The changing of color from dark to light indicates that some of the contaminant in the oil is successfully remove are shown in Figure 4-7. The dark color signifies that the oil is contaminated with acid and other chemical composition. the darker colour for process of transesterification because the results cannot produce free fatty acid (FFA) as discussed in 4.2.

From this process, it can be concluded that most of the contamination contained in the waste cooking oil has been absorbed by Fuller's Earth during contact process. Through the process of reclamation is oil improvement in all aspects of oil as transformer's oil.

4.3.2 Moisture Test

One of the most unaffordable elements that influence the life of insulation in power transformers is water. Water likewise will decrease the performance of transformer oil as an insulation fluid. Moisture is the presence of a liquid, especially water, often in trace amounts.

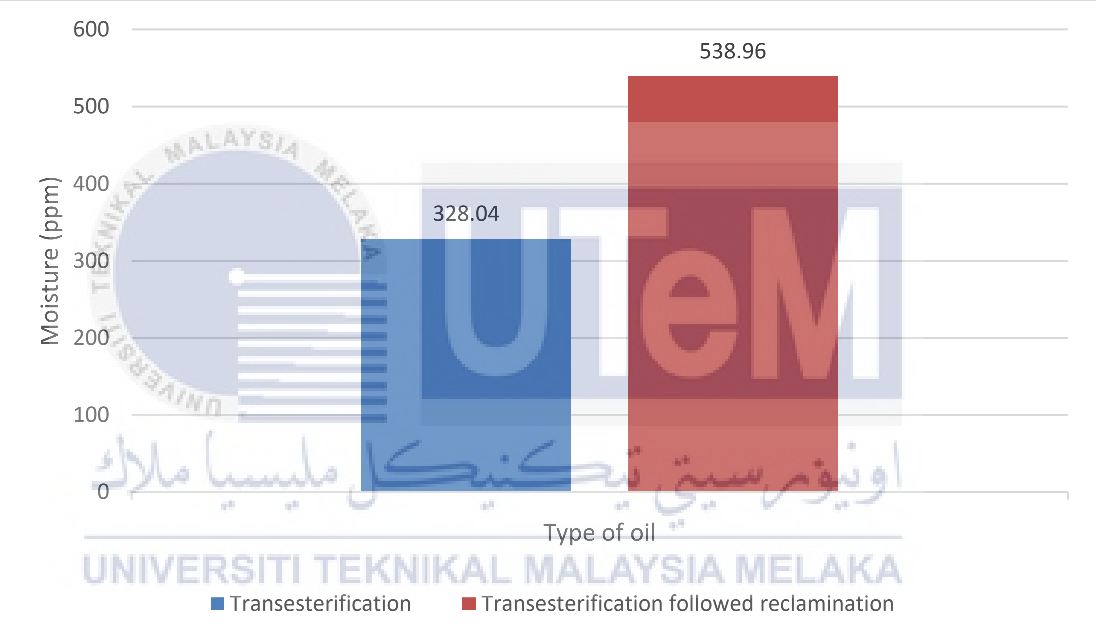


Figure 4-8 : The results of moisture for transesterification and transesterification followed reclamation

The process transesterification followed by reclamation record higher moisture, 538.96ppm. The addition of reclamation process has increased by 210.92ppm moisture while transesterification only on 328.04ppm in Figure 4-8. The increasing moisture influenced by several factors during reclamation process. During the reclamation period, the oil is exposed for a long time to complete the process. The filtration process takes about 5 to 7 hours because mix of oil with fuller's earth and oil filter by vacuum system.

In conclusion, reclamation by contact fail to reduce moisture due to certain factors. The water content was not excessively affected by the accelerated ageing process for this oil sample [6].

4.3.3 Breakdown Voltage Test

In assessing the condition of oil's insulating properties; the breakdown voltage measurement plays an important role. The important factors that determine the breakdown voltage of the oil are moisture, air bubbles, suspended solid matters and acidity of fluid.[9]

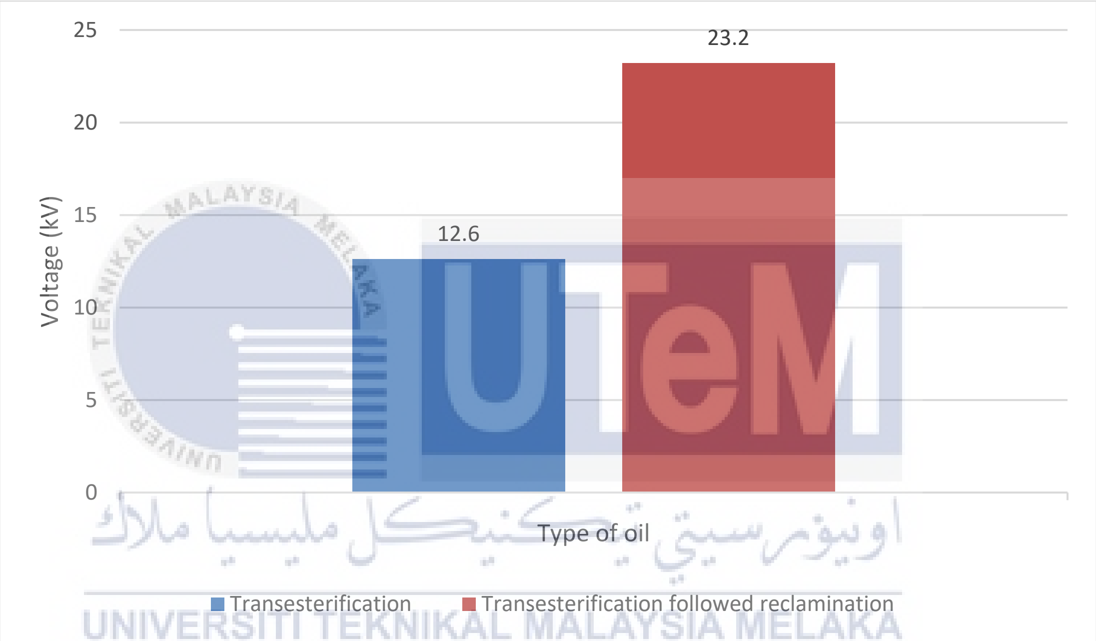


Figure 4-9 : The results of breakdown voltage for transesterification and transesterification followed reclamation

After undergoing transesterification process followed by reclamation record breakdown voltage (BdV) at 23.2kV in Figure 4-9 : The results of breakdown voltage for transesterification and transesterification followed reclamation. Increasing by 10.6kV compared to the transesterification process records only at 12.6kV. The increase in the percentage of enhancement shows the effectiveness of the reclaimed oils for treatment process. The breakdown voltage of the transformer oil is primarily dependent on four factors: moisture content, formation of bubbles, suspended solid particles and acidity of the oil [9]. Refer to the moisture readings it is inconsistent with the stated theory. This is because, as reported by the 4.3.2 sector, the oil moisture readings increased after the reclamation process. Fuller earth absorbed contaminants in oil due to factor breakdown of the voltage breakdown.

In conclusion, the reclamation process excels as a treatment to increase the breakdown voltage. The oil must reach BdV at 30kV through the treatment process to achieve a better level for the transformer oil.

4.3.4 Total Acidity Number Test

The acidity of transformer oil does not give any benefit to the performance of the transformer and its function. At any moment, if the oil is acidified, this will later affect the paper insulation of the winding thus increase the oxidation process in the transformer oil.

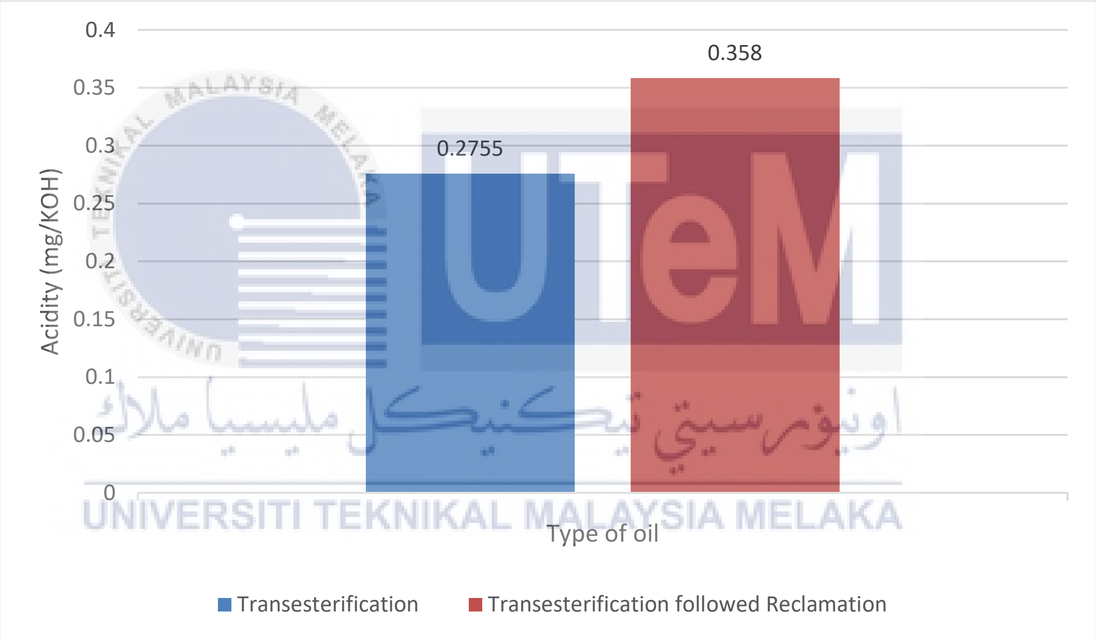


Figure 4-10 : The results of acidity for transesterification and transesterification followed reclamation

The level of oil acidity is an extremely important parameter in determining its quality. Acidity reading is recorded at 0.2755 mg / KOH in the transesterification process. Following reclamation steps, acidity measurements will not be reduced but records at 0.358 mg / KOH. This is because the addition of the reclamation process does not drain the impurities in the oil at all. A mixture of adsorbents with oil to absorb contaminants reclamation process increases the acidity level because the saizing of filter is not too small enough to block the impurities.

In conclusion, the increase in acidity readings for treatment process slightly affects the quality of oil. This can be reduced if the transesterification process is used with smaller filters to achieve the standard.

4.3.5 Ultraviolet-visible Test

Uv-vis refers to absorption spectroscopy in the ultraviolet-visible spectral region of oil. The area below the curve is the absorption level.

The results of the analysis of the treated oil as monitored by turbidity and dissolved decay products are shown in Figure 4-11 : The curve for absorbance in the visible range of spectrum for transesterification and transesterification followed reclamation in Figure 4-11. The greater the reading area, the less the oil quality because of contaminants. It can also be observed that the dissolved decay products removal rate decreases. Table 4-2 presents the undercurve area of transesterification is 346,875. After that, 168.2755 is recorded as a process of improvement through the reclamation process. This is because the oil refining by reclamation process helps spread impurities. Fuller’s earth is naturally occurring earthy substance that has a substantial ability to adsorb impurities, grease, or oils.

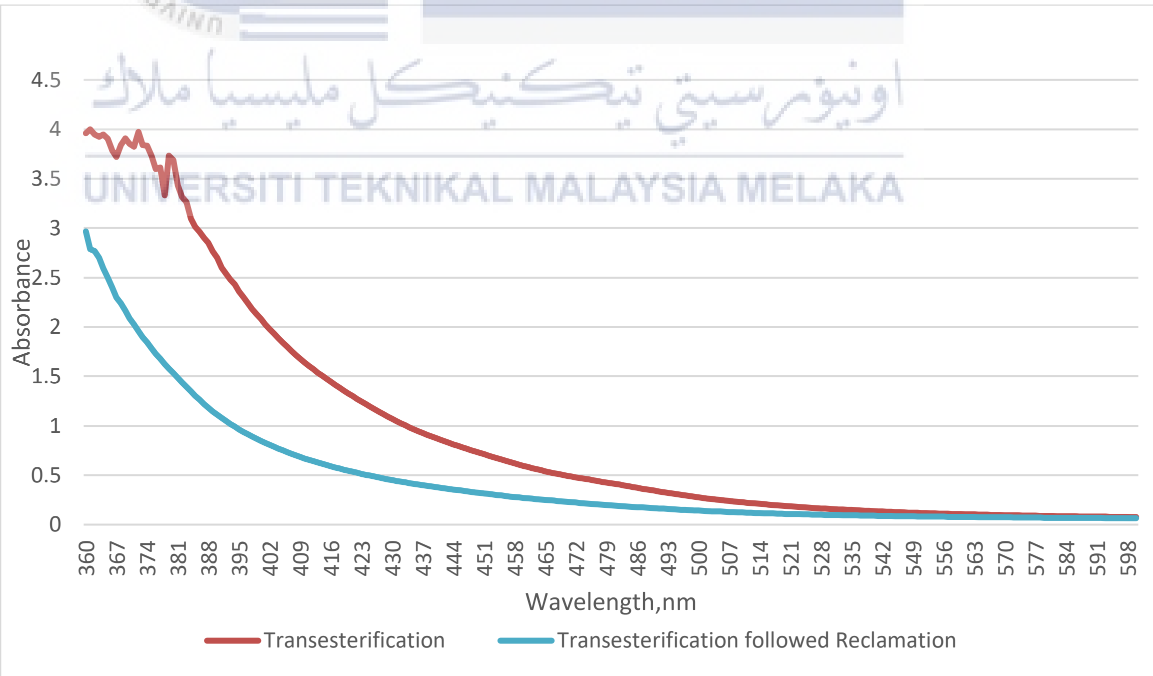


Figure 4-11 : The curve for absorbance in the visible range of spectrum for transesterification and transesterification followed reclamation

Table 4-2 : Area under the curve for transesterification and transesterification followed reclamation

Type	Area Under Curve
Transesterification	346.875
Transesterification followed Reclamation	168.2755

.

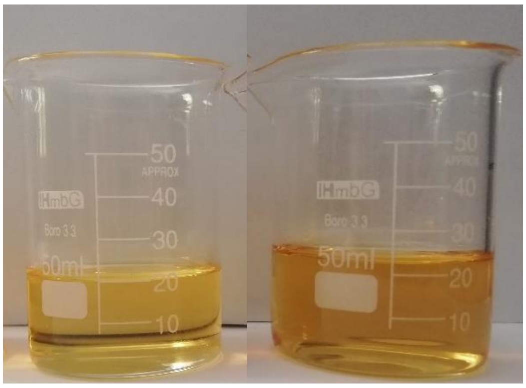
In conclusion, it has been possible to reduce the decay by adding the reclamation process. The contaminants present in the insulating oil can be removed using a suitable adsorbent. It improves the oil quality from transesterification followed reclamation. This extra process which is reclamation records goodness for improvement of oil quality.

4.4 The Sequence of Process to Improvement Waste Cooking Oil Methyl Ester

The transesterification of waste cooking oils is the process for a glyceride reacts with an alcohol in the presence of a catalyst forming fatty acid alkyl esters and an alcohol. Oil Reclamation is the process of restoring the oil’s performance characteristics to its original new like condition. In other words, reclamation allows used oil to be used over and over again without the need for disposal. Find the best sequence to achieve the best level possible. Both processes play an important role in the improvement of waste cooking oil.

4.4.1 Physical Changes of Oil Sample

Figure 4-12 shows process transesterification follows by reclamation (method 2) is clearer than reclamation follow by transesterification (method 1). The changing of color from dark to light indicates that some of the contaminant in the oil is successfully remove. From this process, it can be concluded that most of the contamination contained in the waste cooking oil has been absorbed by Fuller’s Earth during contact process at final steps. Method 1 is closely linked to the results of free fatty acids. The result of free acid without the overall disruption affects the oil colour. The oil colour does not produce any proven results because it also needs electrical testing. In conclusion, both sequences show an increase from the original cooking oil's quality perspective.



(a) (b)

Figure 4-12 : Colour changing : (a) transesterification followed reclamation, (b) reclamation follow by transesterification

4.4.2 Moisture Test

One of the most destructive factors that affect the life of paper insulation in power transformers is water. Water also will reduce the performance of transformer oil as an insulation liquid. The absolute water content of the oil samples was measured by using Karl Fischer Titration.

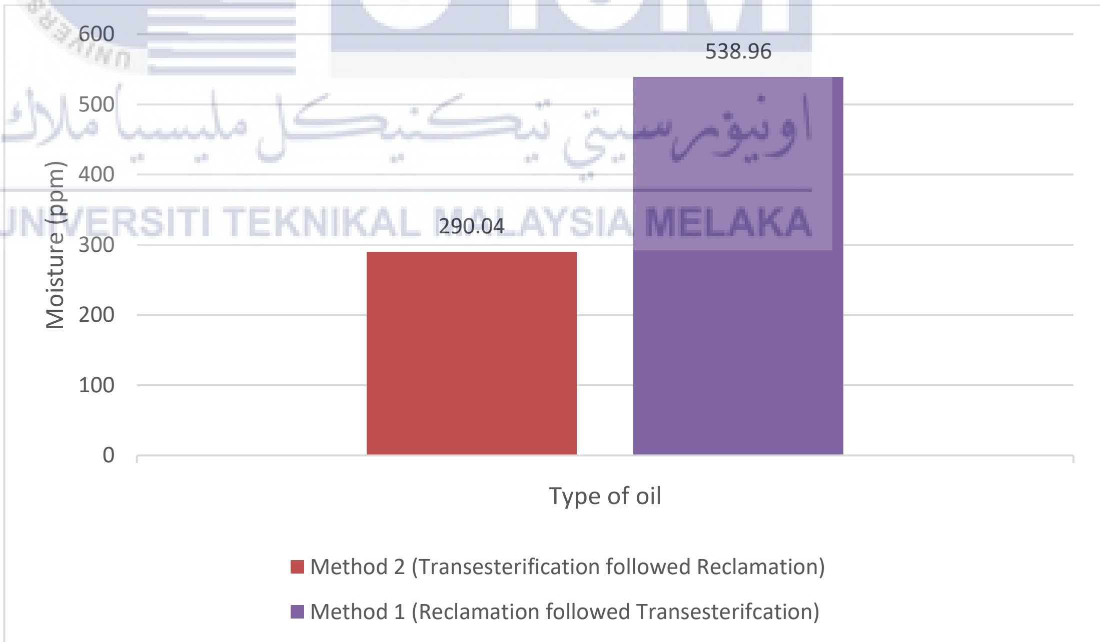


Figure 4-13: The results of moisture for different of sequence process

Method 1 record the higher reading at 538.96ppm while method 2 only 290.04ppm presented in Figure 4-13. Due to some environmental factors, the value difference is very large. Method 2, oil exposed to air during the process of reclamation with the assisted vacuum system, the filter takes a time depend on filter size. Method 1 higher the amount of moisture in the oil because the bleaching and drying process at the end. Especially used for the process in the bleaching phase of the water in excess. Which was not completely removed by the drying process.

Finally, as a result of other readings, decreasing rate should be taken seriously since other readings will be affected. For a better reading by standard, the oil needs to undergo a treatment process. The increase of water vapor in insulation liquid may not only reduce its dielectric strength but also changes the partial electrical field distribution which then will cause in discharge or breakdown of insulation.

4.4.3 Breakdown Voltage Test

Breakdown voltage is very important because the used as isolation oil for transformers. Practically, moisture is very important because it affects the breakdown voltage.

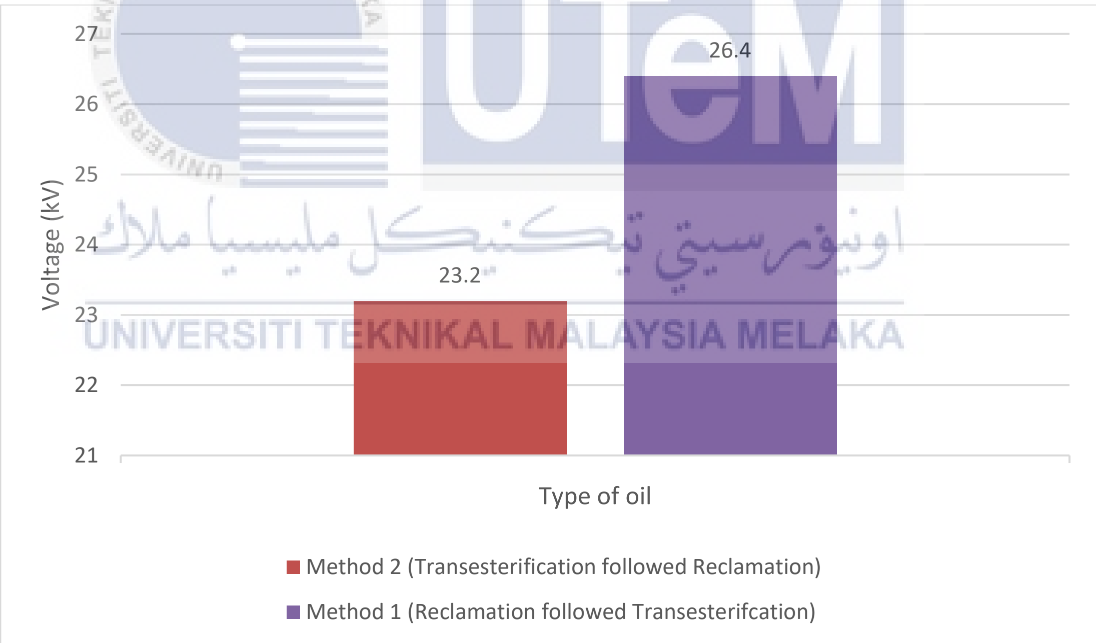


Figure 4-14 : The results of moisture for different of sequence process

BdV values of the compared with method 1, method 2 only at 23.2 kV recorded the highest breakdown voltages of 26.4 kV. The breakdown voltages for each oil sample were normalized with the corresponding oil moisture value. It should be noted that the moisture level of the oil in the above breakdown voltage model is expressed as than moisture content in ppm does not show the significance. Temperature and humidity both affect the dielectric constant but to a very small extent.

In conclusion, breakdown voltage readings must be increased during the treatment process in order to achieve the standard set as insulation oil Breakdown voltage is one of the most important parameters of transformer oil. It is measured when the transformer is taken into use and typically monitored by sampling during its operational lifetime.

4.4.4 Total Acidity Number Test

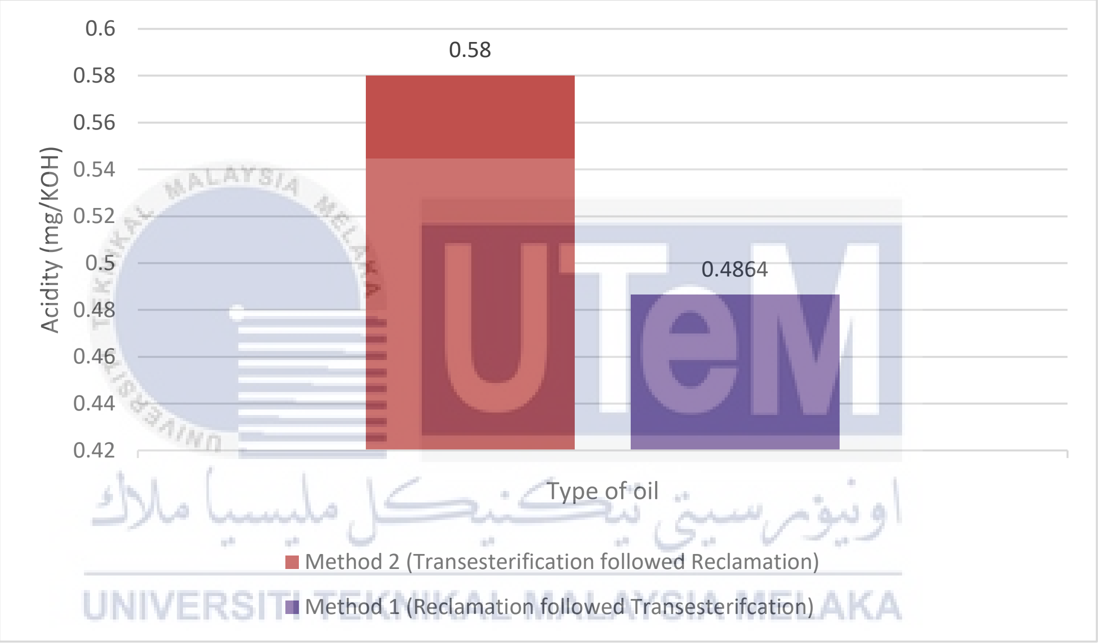


Figure 4-15 : The results of acidity for different of sequence process

An increase in the acidity is an indication of the rate of deterioration of the oil with sludge as the inevitable by-product of an acid situation which is neglected.

Acidity reading methods 1 at 0.4864 mg/KOH but 0.58 mg/KOH at Method 2 are shown in Figure 4-15. It is noted that for acidity readings, method 1 is better. Although both methods are subject to different sequence processes, the difference in reading of 0.0936 mg / KOH is also observed. Method 2 fails to record the best reading because the filter does not remove all, especially full earth. glass microfiber filters cannot cope with all the smaller sizes particles Method 1 is assisted by the final stage of transesterification to reduce acidity even through reclamation at first.

To draw the conclusion, both oils should be reduced to a greater acidity as oil transformers for longer durations. The acidity of oil in a transformer should never be allowed to exceed 0.25mg KOH/g oil. The pore size of filter should be reduced to the optimum level, in specific the reclamation process

4.4.5 Ultraviolet-visible Test

UV Vis spectrophotometer to measure the absorption in the oil. For this analysis is represented by the reading of the under-curve area. The decay contains peroxides, aldehydes, ketones and organic acids, alcohols, anhydride acid and metal soap. The DDP can be used as a useful index for evaluating insulating oil degradation. It changes with a higher rate than TAN [6]

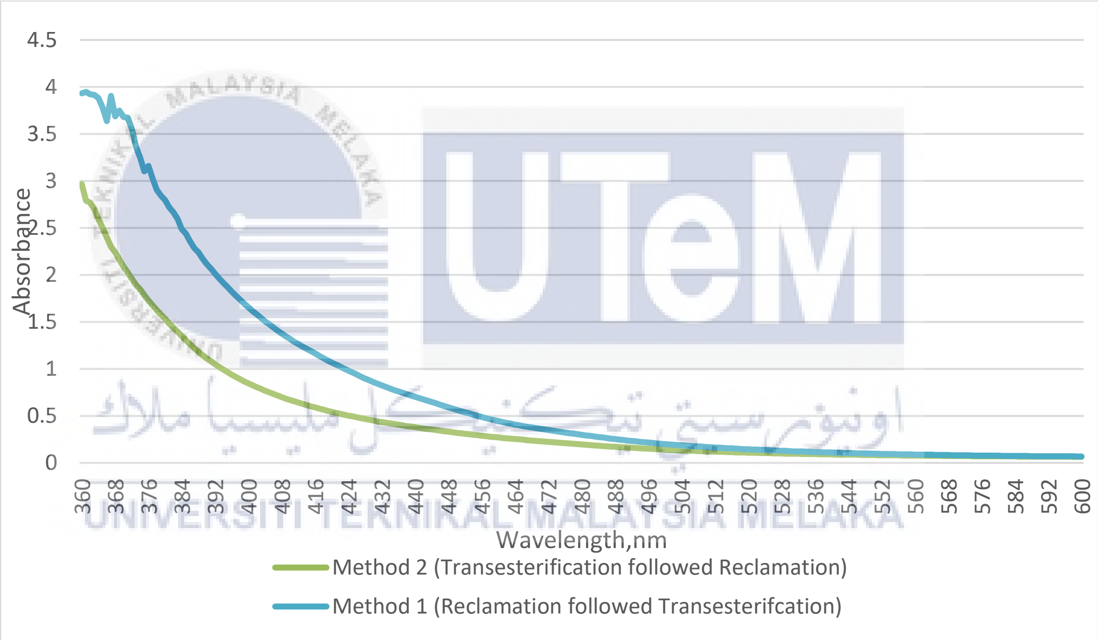


Figure 4-16 : The results of absorbance in the the visible range of spectrum for different of sequence process

Table 4-3: Area under the curve for different of sequence process

Type	Area under curve
Method 1 (Reclamation followed Transesterification)	168.2755
Method 2 (Transesterification followed Reclamation)	289.165

As shown in Figure 4-16, in contrast with the low absorbance shown by new oil and reclaimed oil in the visible spectrum from 360 to 600 nm. Method 2 records the under-curve area is 289.165 which is greater than method 2 at 168.2755 are shown in Table 4.3. The more the adsorption, the larger the under-curve area that mention more contaminants are found in the oil. Method 1 has a smaller area under curve since the contaminants in the transesterification process are reduced successfully. Method 2 has failed to obtain better results, the last reclamation process failed to block contaminants as a result of filtering. The reclamation process at the end provided a comprehensive assessment of the various oil parameters covering a wide range of oil quality parameters. Many factors need to see the transesterification process at the end. Among the main fatty acid (FFA) and glycerol factors. It did not remove it, causing the contaminants to increase completely.

In conclusion, achieve the acceptable level, the undercurve area must be lowered. Method 2 enables better readings to be recorded if the filter sizing is reduced to remove oil impurities. As UV-Visible spectroscopy gives the clear results, it can be used as a tool for investigating the transformer oil for its deterioration and ageing due to electrical and thermal stresses.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The experimental work presented in this thesis contributes to a further understanding on the waste cooking oil (WCO) methyl ester by reclamation behaviour for distribution transformers, properties and characteristics of this oil, and its effect on transformer operations. WCO has been seen as a potential substitute, because it is environmentally friendly, biodegradable and renewable. However, a lot of studies need to be carried out before it can be used as alternative power transformer oil commercially. Thus, this work has been carried out to investigate several electrical and physical properties of transformer oil, such as breakdown voltage (BdV), moisture content, total acidity number (TAN), and ultraviolet–visible (uv-vis).

The difference value of sodium hydroxide (NaOH) is used in the process of transesterification of WCO describes the relationship between catalysts and electrical properties. Good additives have been produced for the TAN readings. The more NaOH records a decrease in acid readings. The readings of acidity are closely related. Where uv-vis also recorded a good decline when NaOH is added. Moisture reading shows the best WCO + 7 g NaOH reading. This means that the addition of NaOH does not have a significant impact on moisture readings. When referring to moisture readings, it definitely shows that 7 g NaOH records the best BdV because it is related. In the end, WCO + 10 g NaOH provides the best overall results, even failure in voltage breakdown and reading of moisture. By decreasing the humidity, BdV can be increased through other treatments.

In order to increase the electrical properties, WCO methyl ester conducts a reclamation process. For TAN and moisture readings to demonstrate deterioration in which readings are recorded. The reading shows the effects of electrical properties. However, uv-vis and BdV is observed improvements in quality oil. Bdv posted a good increase, where there was a decline in uv-vis. It shows moisture readings and TAN disrupts due to other factors. Generally, improvements in the oil quality of WCO methyl ester are successfully recorded through the reclamation process.

The sequence process must also be taken seriously where it plays an important role in the results of the WCO methyl ester. Method 1 is reclamation followed transesterification while method 2 is transesterification followed reclamation. If evaluated on U\uv-vis reading and TAN reading, method 2 records better readings. It explains that contaminants can be reduced more by method 2. Unlike the moisture readings and the BdV where method 1 records the best reading. It is commonly assisted by the last transesterification process and environment. As a summary, both methods gives a great decline compared to the pure WCO readings. Method 2 was selected as the best order for the WCO methyl ester treatment process. Though, moisture readings and BdV for Method 2 are not the best, but both properties can be improved through treatment processes such as nitrogen gas.

All things considered, processes of reclamation and transesterification shows a great change for pure WCO for improvement. However, many factors need to be taken into consideration in the process of improving oil quality.

5.2 Future Works

Based on the findings obtained in the present study, helpful in identifying the most sensitive properties with respect to reclamation and transesterification process for waste cooking oil (WCO). Eventually, this knowledge data base will also be helpful in evolving a condition monitoring strategy for insulation oil transformers.

The present and the current research have thrown a few interesting problems in further research could be undertaken, these problems are outlined below:

i) Reducing the pore size of the filter to achieve maximum filtration.
ii) Operate the reclamation process in a closed area and do not allow oil to be exposed to avoid increasing moisture reading.
iii) Maximum use ratio for catalyst and methanol for transesterification processes for maximum FFA yield.
iv) Find an alternative to the Earth Fuller because it affects TAN reading.

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APPENDICES

APPENDIX A FINAL YEAR PROJECT GANTT CHART

Milestone	Year	2018				2019				
	Month / Task	9	10	11	12	1	2	3	4	5
1	Get the title	■								
2	Find reference (Journal, IEEE)	■	■	■	■	■	■	■	■	
3	Literature Review	■	■	■	■	■	■	■	■	■
4	Doing Transesterification process			■	■					
5	Doing Reclamination process					■	■			
6	Record and data collection				■	■	■			
7	Result analysis				■	■	■	■	■	
8	Report Writing	■	■	■	■	■	■	■	■	■

APPENDIX B THE RECLAMATION PROCESS TO IMPROVEMENT AFTER TRANSESTERIFICATION DATA

Table B.1 : The result of moisture content for transesterification process

WCO + 5g NaOH		
No.	Sample weight (g)	Moisture (ppm)
1	0.9544	346.5
2	0.8314	306.0
3	0.8286	299.7
4	0.8669	309.8
5	0.7433	313.5
Average		315.1
WCO + 7g NaOH		
No.	Sample weight (g)	Moisture (ppm)
1	0.8356	189.5
2	0.8295	185.3
3	0.9529	186.1
4	0.6556	193.5
5	0.6793	249.5
Average		200.78
WCO + 10g NaOH		
No.	Sample weight (g)	Moisture (ppm)
1	0.8726	280.2
2	0.8594	284.2
3	0.8377	333.6
4	0.9346	330.6
5	0.7315	371.3
Average		319.98

Table B.2 : The result of acidity for transesterification process

WCO + 5g NaOH		
No.	Sample weight (g)	Acidty (mg/KOH)
1	5.0158	0.2373
2	5.0328	0.2324
3	5.0012	0.2359
Average		0.2352
WCO + 7g NaOH		
No.	Sample weight (g)	Acidty (mg/KOH)
1	5.0041	0.3005
2	5.1146	0.2654
3	5.0084	0.2606
Average		0.2755
WCO + 10g NaOH		
No.	Sample weight (g)	Acidty (mg/KOH)
1	5.0167	0.3413
2	5.0212	0.3390
3	5.0212	0.3420
Average		0.3408

Table B.3 : The result of breakdown voltage WCO + 5g NaOH for transesterification process

Test	**1**	**Test**	**2**
Humidity%	52.2	Humidity%	51.3
Room temperature ºC	26	Room temperature ºC	25.2
Oil temperature ºC	24.9	Oil temperature ºC	27
Trial	BdV (kV)	Trial	BdV (kV)
1	26	1	28
2	16	2	14
3	9	3	7
4	6	4	6
5	6	5	7
Average	13	Average	12
Test	**3**	**Test**	**4**
Humidity%	27	Humidity%	26.8
Room temperature ºC	25	Room temperature ºC	25.1
Oil temperature ºC	27	Oil temperature ºC	49.8
Trial	BdV (kV)	Trial	BdV (kV)
1	24	1	1
2	15	2	2
3	8	3	2
4	6	4	1
5	2	5	2
Average	11	Average	2
Test	**5**		
Humidity%	49.6	**Average total = 7.8kV**	
Room temperature ºC	25.1		
Oil temperature ºC	27		
Trial	BdV (kV)		
1	23		
2	1		
3	1		
4	1		
5	1		
Average	5		

Table B.4 : The result of breakdown voltage WCO + 10g NaOH for transesterification process

Test	**1**	**Test**	**2**
Humidity%	48.8	Humidity%	49.5
Room temperature ºC	25.2	Room temperature ºC	25.3
Oil temperature ºC	27	Oil temperature ºC	26.8
Trial	BdV (kV)	Trial	BdV (kV)
1	7	1	9
2	7	2	6
3	8	3	6
4	8	4	6
5	7	5	6
Average	7	Average	7
Test	**3**	**Test**	**4**
Humidity%	47.7	Humidity%	47.9
Room temperature ºC	25.1	Room temperature ºC	25.2
Oil temperature ºC	26.8	Oil temperature ºC	26.8
Trial	BdV (kV)	Trial	BdV (kV)
1	8	1	8
2	8	2	7
3	6	3	6
4	6	4	6
5	6	5	2
Average	7	Average	6
Test	**5**		
Humidity%	50.4	**Average total = 7kV**	
Room temperature ºC	25.2		
Oil temperature ºC	26.7		
Trial	BdV (kV)		
1	25		
2	4		
3	2		
4	5		
5	6		
Average	8		

Table B.5 : The result of breakdown voltage WCO + 5g NaOH for transesterification process

Test	**1**	**Test**	**2**
Humidity%	48.8	Humidity%	49
Room temperature ºC	24.8	Room temperature ºC	24.9
Oil temperature ºC	26.8	Oil temperature ºC	26.8
Trial	BdV (kV)	Trial	BdV (kV)
1	26	1	13
2	12	2	11
3	13	3	11
4	12	4	9
5	12	5	9
Average	15	Average	11
Test	**3**	**Test**	**4**
Humidity%	50.1	Humidity%	49.1
Room temperature ºC	24.8	Room temperature ºC	24.8
Oil temperature ºC	26.6	Oil temperature ºC	26.6
Trial	BdV (kV)	Trial	BdV (kV)
1	9	1	6
2	8	2	8
3	7	3	8
4	7	4	7
5	7	5	8
Average	8	Average	7
Test	**5**		
Humidity%	50		
Room temperature ºC	24.8	**Average total = 9.8kV**	
Oil temperature ºC	26.6		
Trial	BdV (kV)		
1	9		
2	10		
3	7		
4	8		
5	7		
Average	8		

APPENDIX C THE INFLUENCES OF CATALYST FOR TRANSESTERIFICATION PROCESS DATA

Table C.1 : The result of moisture for transesterification followed reclamation process

No.	Sample weight (g)	Moisture (ppm)
1	1.0687	517.0
2	0.9133	511.5
3	0.8851	568.5
4	1.0348	513.9
5	0.6950	583.8
Average		538.96

Table C.2 : The result of acidity for transesterification followed reclamation process

No.	Sample weight (g)	Acidty (mg/KOH)
1	5.0774	0.2781
2	5.0410	0.3943
3	5.0052	0.4016
Average		0.358

Table C.3 : The result of breakdown voltage for transesterification followed reclamation process

Test	**1**	**Test**	**2**
Humidity%	54.5	Humidity%	55.3
Room temperature ºC	23.7	Room temperature ºC	23.5
Oil temperature ºC	26.9	Oil temperature ºC	27.1
Trial	BdV (kV)	Trial	BdV (kV)
1	14	1	23
2	8	2	24
3	10	3	32
4	10	4	32
5	10	5	31
Average	18	Average	28
Test	**3**	**Test**	**4**
Humidity%	52.3	Humidity%	53.1
Room temperature ºC	23.6	Room temperature ºC	23.4
Oil temperature ºC	26.5	Oil temperature ºC	25.8
Trial	BdV (kV)	Trial	BdV (kV)
1	36	1	19
2	28	2	32
3	16	3	26
4	27	4	24
5	22	5	30
Average	26	Average	26
Test	**5**	**Average total = 24.8 kV**	
Humidity%	57.8		
Room temperature ºC	23.9		
Oil temperature ºC	25.9		
Trial	BdV (kV)		
1	28		
2	21		
3	25		
4	28		
5	27		
Average	26		

APPENDIX D THE SEQUENCE OF PROCESS TO IMPROVEMENT WASTE COOKING OIL METHYL ESTER DATA

Table D.1 : The result of moisture for reclamation followed transesterification process

No.	Sample weight (g)	Moisture (ppm)
1	0.8689	252.9
2	0.8689	280.0
3	0.7941	283.1
4	0.8574	340.2
5	0.9333	294.0
Average		290.04

Table D.2 : The result of acidity for reclamation followed transesterification process

No.	Sample weight (g)	Acidty (mg/KOH)
1	5.0774	0.2781
2	5.0410	0.3943
3	5.0052	0.4016
Average		0.358

Table D.3 : The result of breakdown voltage for reclamation followed transesterification process

Test	**1**	**Test**	**2**
Humidity%	55.2	Humidity%	53.9
Room temperature ºC	24.5	Room temperature ºC	23.8
Oil temperature ºC	28.9	Oil temperature ºC	27.2
Trial	BdV (kV)	Trial	BdV (kV)
1	35	1	38
2	32	2	25
3	24	3	25
4	27	4	25
5	31	5	27
Average	30	Average	28
Test	**3**	**Test**	**4**
Humidity%	53.7	Humidity%	52.9
Room temperature ºC	24	Room temperature ºC	23.3
Oil temperature ºC	26.8	Oil temperature ºC	26.5
Trial	BdV (kV)	Trial	BdV (kV)
1	26	1	30
2	26	2	23
3	26	3	25
4	22	4	25
5	22	5	25
Average	24	Average	26
Test	**5**	**Average total = 27 kV**	
Humidity%	54		
Room temperature ºC	23.6		
Oil temperature ºC	26		
Trial	BdV (kV)		
1	26		
2	27		
3	29		
4	27		
5	24		
Average	27		

Table D.3 : The result of breakdown voltage for transesterification process

Test	**1**	**Test**	**2**
Humidity%	67.5	Humidity%	65.1
Room temperature ºC	27.9	Room temperature ºC	26.1
Oil temperature ºC	29.7	Oil temperature ºC	29.7
Trial	BdV (kV)	Trial	BdV (kV)
1	10	1	14
2	12	2	13
3	12	3	13
4	12	4	14
5	12	5	12
Average	12	Average	13
Test	**3**	**Test**	**4**
Humidity%	70	Humidity%	69.3
Room temperature ºC	26.8	Room temperature ºC	27.5
Oil temperature ºC	29.2	Oil temperature ºC	29
Trial	BdV (kV)	Trial	BdV (kV)
1	13	1	12
2	12	2	13
3	13	3	12
4	13	4	13
5	14	5	12
Average	13	Average	12
Test	**5**		
Humidity%	69.6	**Average total = 12.6 kV**	
Room temperature ºC	27.3		
Oil temperature ºC	28.7		
Trial	BdV (kV)		
1	14		
2	12		
3	13		
4	12		
5	12		
Average	13		