UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF BIODIESEL PRODUCTION FROM WASTE COOKING OIL USING TAGUCHI METHOD

ANIS BINTI MOHAMAD TAIB

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY
(Technology Maintenances) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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ANIS BINTI MOHAMAD TAIB

A thesis submitted
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2022

DECLARATION

I declare that this Choose an item. entitled " Optimization Of Biodiesel From Waste Cooking Oil Using Taguchi Method" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Name : Anis Binti Mohamad Taib

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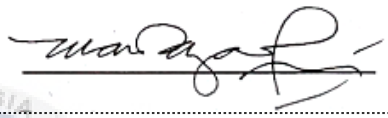
APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Technology Maintenances) with Honours.

Signature : 

Supervisor Name : Mahanum binti Mohd Zamberi

Date : 28/01/2022

DEDICATION

From the bottom of my heart this dedication specially for may parents Mohamad Taib bin Abdul Rahman and Aziah Binti Alang Ahmad, my sibling, my friend and also my teammates who being the most supportive people for me to go through this stage. With their word of encouragement and strong support to my system i can go this far in my life. To all UTeM Lecturer and staff who help me during the completion of research, special thanks for your dedication and never endless guidance for me. For me to go until this far seem very unbelieveble without guidance from my supervisor who always remind and guide my research to keep going on track. Despite all the memory of bittersweet completing studies and research, memory we endure together will remain forever in our mind.

ABSTRACT

The rising expense of petroleum products, as well the contribution of carbon emissions from petroluem diesel, which are damaging to the environment and human health, has prompted researchers looking for another means to substitute non-renewable energy. As an alternative, biodiesel shown a promising future to a global as a substitute to the fossil fuel. The main purpose of this research is to promote optimizing production of biodiesel from waste cooking oil using conventional batch tranesterification method. By utilizing the alkaline catalyst potassium hydroxide (KOH) all important variable impacting the overall biodiesel conversion such as methanol to oil molar ratio, catalyst loading, reaction time, reaction temperature has been examined. In order to achieve optimum yield production, all variables impacting the conversion of waste cooking oil were investigated by implementing Taguchi Method L9 (3^4) orthogonal array. All the produces biodiesel will be analyzed accordance to ASTM D6751 and EN14214 standard.

ABSTRAK

Peningkatan harga petroleum serta kesan pelepasan gas berbahaya yang membahayakan kesihatan manusia dan alam sekitar telah mendorong para pengkaji mencari alternatif lain untuk menggantikan sumber yang tidak boleh diperbaharui ini. Biodiesel merupakan salah satu alternatif terbaik dan mempunyai masa depan cerah untuk menggantikan bahan api fosil. Tujuan utama kajian ini adalah untuk meningkatkan dan mengoptimumkan penghasilan biodiesel dari minyak masak terpakai menggunakan kaedah transesterifikasi kumpulan konvensional. Penggunaan kalium hidroksida(KOH) sebagai pemangkin alkali serta pemboleh ubah yang memberi impak besar kepada pertukaran minyak masak terpakai kepada biodiesel, Contoh pemboleh ubah adalah methanol kepada nisbah minyak, reaksi pemangkin, reaksi masa, suhu tindak balas. Tuntasnya, jika ingin mendapatkan data tindak pemboleh ubah yang optimum, kesemua pemboleh ubah yang dimanipulasi hendaklah dianalisa menggunakan kaedah taguchi L9 (3^2) tatacara ortagonal. Setiap penghasilan biodiesel akan dianalisa mengikut piawai ASTM D6751 dan EN14214.

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Last but not least, from the bottom of my heart a gratitude to my beloved parents Mohamad Taib Bin Abdul Rahman and Aziah Binti Alang Ahmad, for encouragements and who have been the pillar of strength in all my endeavors. My special thanks for my teammates, Tuan Ismail Bin Tuan Zakaria, and Muhammad Ariff Bin Noor Salleh for their patience, idea and understanding. Finally, thank you to all the individuals who had provided me the assistance, support and inspiration to embark on my study.

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LIST OF SYMBOLS AND ABBREVIATION

D,d	-	Diameter
ASTM	-	American Society for Testing and Materials
EN	-	Europian Committe of stadardizations
WCO	-	Waste Cooking Oil
FFA	-	Free Fatty Acid
DoE	-	Design Of Experiment
OA	-	Orthogonal Array
ANOVA	-	Analysis Of Variance
S/N	-	Signal to Noise Ratio
RSM	-	Response Surface Method
AV	-	Acid Value
B100	-	100% Biodiesel
FAME	-	Fatty Acid Methyl Ester
GCMS	-	Gas Chromatography Mass Spectrometry
KOH	-	Potassium Hydroxide
MeOH	-	Methanol
MS	-	Mean Square
PCR	-	Percentage Contribution Ratio
SV	-	Saponification Value
TAN	-	Total Acid Number
NOx	-	Nitrogen Oxide
EGR	-	Exhaust Gas Recirculation

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CHAPTER 1

INTRODUCTION

1.1 Background

Sustainability and energy problem have become more challenging starting from revolution industry time. Researcher Taghizade in (2016) stated that from all around the world are actively working on finding energy options that are reliable, secure, clean, economical, and sustainable to use. Futhermore, taken statement from Rezania in (2020) recently developing country actively working on finding new sources to replace non-renewable energy. Population arise around the world was one of the main reason for society to find another replacement for non-renewable energy that been said reduce year pass by with the population arise together with the demand for consuming non-renewable energy. Similarly with what Tavares (2017) said the increase demand of energy usage will adverse to economy global that lend so much on energy. Right now fossil fuel still being the major production of diesel around the world.

Nonetheless, sources of non-renewable energy supply was limited. This energy supply contribute to so many health and environmental problem. In the same way in study by Alias (2018) looking on another context, fossil fuel energy cannot be found everywhere. Moreover, only certain country, have the resources to import crude oil around the world . In this situation, so many step and level of process, the price of diesel in certain country with no resources was so expensive. Moving more to the future, so many contribution from

researcher in order to reduce the dependance on non-renewable energy. As a result, biodiesel might be viewed as a viable option for reducing the significant reliance on diesel fuels.

Biodiesel known as one of well known renewable energy to reduce greenhouse gas emmisions effect, and this production was in effort to replace the usage of non-renewable energy (Hanaki and Portugal-Pereira, 2018). The transportation sector's need for biodiesel is gradually increasing. Many countries for example Europian and the United State, have established energy laws requiring the use of greater biodiesel in their transportation sectors. Statistic from Idris on (2017) conclude that from 0.84 billion liters in 2000 to 20.2 billion liters in 2010 and 32 billion liters in 2014, worldwide biodiesel output has increased dramatically. Natural and promising economical in biodiesel industry was a brilliant choice source of sustainable energy. Liquid biofuel is an essential in daily life to fuel vehicle and engines. Futhermore, study together by Singh and Verma in (2019) admittedly that to produce biodiesel, process of transesterification take a big part in converting oil and glycerol into fatty acid alkyl ester and glycerol in the existence of an alcohol (methanol and ethanol) with suitable catalyst.

Romano and Sorichetti (2011) together also agree that common raw feestock include waste cooking oil, vegetable oil, grease, or fat from animal can be used to reduced wear and tear on engine. It should be brought to mind that, if the biodiesel can be a totally renewable fuel, it must be made from animal fats and vegetable oil, along with a biomass-derived alcohol, such as bioethanol, rather than a petrochemical product. Several nations, including Spain and Brazil, are conducting research in this area.

Consequently, the main purpose of this study is to get optimum yield biodiesel from waste cooking oil using conventional batch transesterification in the presence of potassium

hydroxide (KOH) as catalyst which is evidence by Zahan and Kano in (2018). To do so, all parameter impacting the overall biodiesel conversion such as methanol to oil molar ratio, catalyst loading, reaction time, reaction temperature were optimized using Taguchi method. The produced of biodiesel will be analyzed accordance to ASTM D6751 and EN14214 standard.

1.2 Problem Statement

Rising cost of petroleum product and contribution of carbon release from petroleum diesel that harmfull to environment and health, trigger the researcher to find another alternative way to replace non-renewable energy. Increasing number release emmision of greenhouse effect worsening the situation. High usage of vehicle on the road, release high emission of carbon dioxide that come from incomplete. The challenging in biodiesel industry was the the cost production of biodiesel still higher compare to petroleum based. The factor consist of cost of raw material and processing cost.

Untreated waste cooking oil was one of the sources that contribute to pollution. As a result, making biodiesel from used cooking oil was a great option, and more research on waste cooking oil characterisation is needed. Another issue with the usage of diesel is the worsening impact of rising greenhouse gas emissions in the environment. This is due to the significant carbon dioxide emissions caused by incomplete diesel fuel burning in automobiles. With many data to be analyse and sample to be produce. Taguchi method being used to optimized the parameter of methanol to oil molar ratio, catalyst loading, reaction time and reaction temperature.

1.3 Research Objective

The main purpose of this research is to enhance the production of biodiesel from waste cooking oil and optimization the transesterification parameter. Specifically, the objectives are follow

a. To produce biodiesel from waste cooking oil using potassium hydroxide (KOH) via batch conventional method.
b. To optimize all the variables such as methanol to oil molar ratio, catalyst loading, reaction, reaction temperature in order to produce optimum yield production using Taguchi Method.
c. To validate physical and chemical properties of produce biodiesel accordance to ASTM D6751 and EN14214.

1.4 Scope of Research

The scope of this study consist of four important element:

a. Collecting raw waste cooking oil from various industry resources and identifying the important properties of the raw oil.

b. Produce the biodiesel using conventional method via transesterification process with the aid of alcohol and potassium hydroxide as an alkaline catalyst.

c. Varying all important parameter involved such as methanol to oil molar ratio, catalyst concentration, reaction time, reaction temperature.

d. Optimize the production process by implmenting statistical analysis, Taguchi Method.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Biodiesel research is becoming a significant aspect of science society's future growth. As a result of the crisis and problems caused by petroleum-based fuel, biodiesel research has developed. With the growing interest in manufacturing biodiesel, characteristics and catalysts are being investigated in order to provide the finest possible diesel quality (Bhattarai, 2011). Agree by Ashnani (2014) to boost biodiesel demand, researchers are currently looking for low-cost, high-quality raw materials. The biggest problem at the moment was determining the most appropriate manufacturing phase for creating the highest-grade biodiesel. Furthermore, Esmaeili in (2019) state that the production and usage of fossil fuel in engine in internal combustion affecting environmental such as air pollution and increasing amount carbon dioxide release in the air and impacting on the global temperature.

In recent situation diesel still dominate the demand of fuel usage in transportation, agriculture, power that being generated and industrial appliances according to Rajalingam (2016). Biodiesel is a renewable energy source in this environment, and as a result, its market is expanding. Tavares in (2017) state that a wide range of feedstock are being used as raw materials in biodiesel manufacturing to meet the quality standard. Transesterification of triglycerides with short-chain alcohols such as methanol or ethanol, catalyzed by an acid or a base, to produces biodiesel.

2.2 Raw feedstock of oil

Biodiesel can be produce from any plant or animal derived oil. Throughout the year so many production of biodiesel being proven that every oil give a different properties and so many comparison being made to improve the quality of biodiesel follow by the standard (Bhattarai, 2011). Type of raw feestock oil was tabulated below in Table 2.1 and usually biodiesel produced from high fatty acid feedstock such asfats and recycled oil. Animal oil and vegetable fat are one kind of triglyceride molecule which is three fatty acid group were ester and attach to one glycerol molecule.

Table 2.1 Type of raw biodiesel feedstock oil (Babu, 2013)

Group	Oil Sources
Major Oil	Coconut (Copra), corn (maize),cottonseed, canola (a variety of rapeseed), olive, peanut (groundnut), sunflower, sesame, soybean, and sunflower.
Nut Oil	Almond, cashew, hazelnut, macadamia, pecan, pistachio and walnut.
Other Edible Oil	Amaranth, apricot, argan, artichoke, avocado, babassu, bay laurel, beech nut, ben, Borneo tallow nut, carob pod (algaroba), cohune, coriander seed, false flax, grape seed, hemp, kapok seed, lallemantia, lemon seed, macauba fruit (Acrocomia sclerocarpa).
Inedible Oil	Algae, babassu tree, copaiba, honge, jatropha or ratanjyote, jojoba, karanja or honge, mahua, milk bush, nagchampa, neem, petroleum nut, rubber seed tree, silk cotton tree, and tall.

2.2.1 Vegetable Oil

To begin with researcher Chen (2018) shown in his study that vegetable oil known widely as renewable energy, because the vegetable source was easy to get and can widely produced. Vegetable oil also predicted as inexhaustible with the energy content close to diesel fuel properties. One of the most content of fatty acid was refined oil and and fats.Using vegetable oil as a diesel oil have more advantages such as, liquidity, readily availability, renewability, low sulfur and aromatic content. By Yaakob in (2013) interprete the vegetable oil also has disadvantage which is high viscosity, votality, and rectivity to unsaturated hydrocarbon chains. United States has become the largest producer of biodiesel from soybean as shown in Figure 2.1. United State one of the country that has bulk production of soybean. Another reason was soybean is cheap because it can be easily found everywhere. Figure 2.1 also show another common feedstock that being produces in United State. The more it properties similar to existing diesel fuel with cheap price and production, the more it being comersialize and promoted.

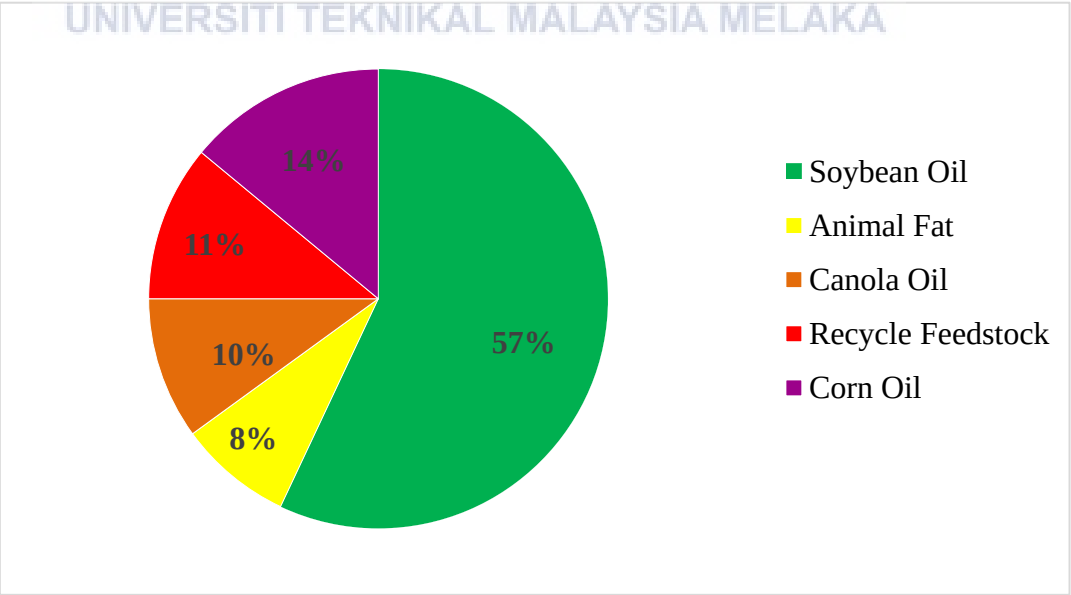

Figure 2.1 U.S biodiesel Production in 2019. Chen (2018)

2.2.2 Waste Cooking Oil

The trend of fast food and snacks nowaday contribute into so much food and product of frying. The waste from cooking oil need to manage accurately in order to avoid harm to people it surely can cause negative impact to environment if not being managed properly. The recycling of Waste Cooking Oil (WCO) using transesterification that producing biodiesel can be sustainable in order to minimize waste dumping Ulfah, (2019). Cooking oil is a glycerol ester composed mainly of various essential fatty acids that can only be dissolved in organic solvents. Originally source of waste cooking oil is plant-based lipids for example olive oil, and canola oil, palm oil, coconut oil, or lipid-based animals, such as clarified butter (ghee) and butter (Jacob, 2013).

At room temperature, as Azahar (2017) state that waste is classified as fat and grease in liquid form. This type of waste is produce by food outlets, food industry, and households as a result of food preparation. However, due to its inability to dissolve in water, it becomes a pollutant in the environment. Observation by Nur and Wan in (2016) that been done to waste cooking oil resulting of chemical compund which is oleic acid 43.67%, palmitic acid 38.35% and linoleic acid 11.39%. With this compound characteristics the chances to crack is higher by catalyst cracking or thermal cracking.

In Malaysia, the percent of people who have awareness to recycle the waste cooking oil still low, that why the percent of collection waste cooking oil in malaysia one of the lowest compared to other country study by Alias, (2018). Pie chart in Figure 2.2 shows the collection of waste cooking oil based on country. Another study from Dhawane (2018) said that usually waste cooking oil (WCO) is often mixed with new oil many times before being

dumped for use in local restaurants or stores. In the household normally it will not be kept but thrown into the drainage or sewerage.

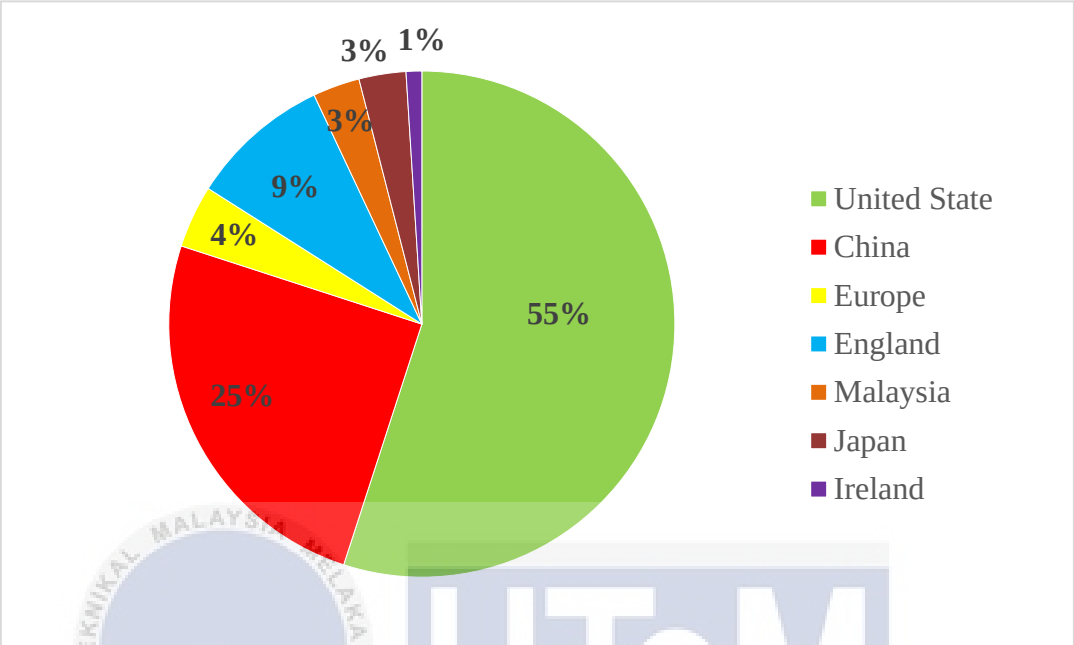

Figure 2.2 Collection waste cooking oil based on country (Azahar, 2016)

2.3 Biodiesel production technology

There were several technology being used in order to produce biodiesel, such as direct use and blending, micro emulsions, transesterification, and pyrolysis. Figure 2.3 below interprete the four widely used technology in biodiesel production. The mono alkali ester, which is produced by animal fat or vegetable oil, is the true form of biodiesel. When biodiesel is used as a fuel, the quantity of carbon emitted during the combustion process is equivalent to the amount of carbon absorbed by an animal or plant throughout its whole existence. As a result, emissions from green biofuel burning will be minimal (Rajalingam, 2016).

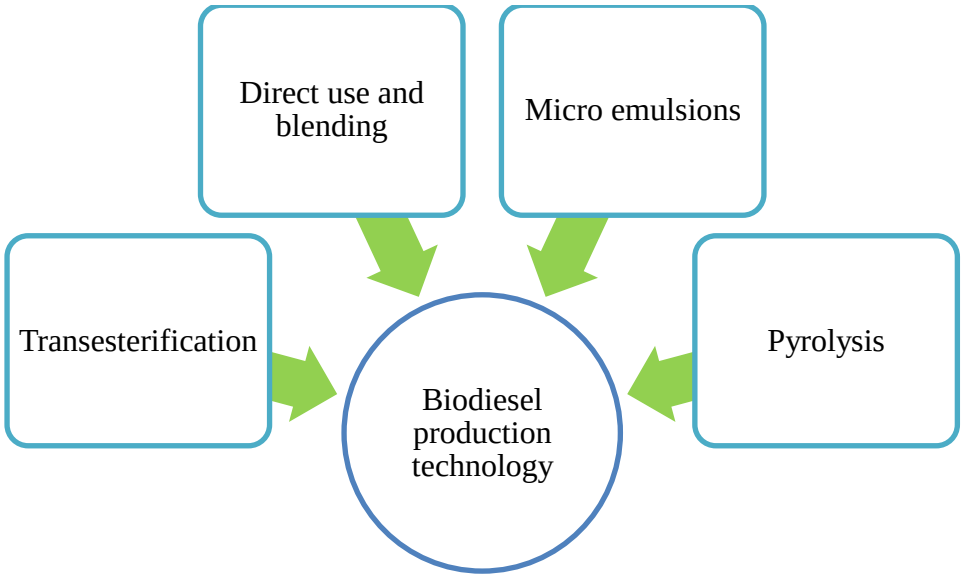

Figure 2.3 Biodiesel production technology

2.3.1 Direct use and blending

In direct use and blending, animal fat or vegetable oil can be utilised as a fuel since it has a high heating value and can provide enough power. However, because of its different properties, it cannot be utilised in the engine without modification conventional fossil fuels are mixed directly with alternative fuels to prevent such issues. This type of mixing will improves fuel quality. The bio oil and diesel mixes will be in various ratios, such as 10:1, 10:2, 10:3, and so on (Rajalingam, 2016).

The study conducted by Wu and Wu in (2013), applied the Taguchi method in proton exchange membrane fuel cells having the best possible combination of experimental variables. As said by Nataraj in (2005)**,** the Taguchi technique was shown to be effective in estimating the impact of various design variables on engine emissions.

2.3.2 Micro-Emulsions

Microemulsions using solvents such as methanol, ethanol, and 1-butanol were used when dealing with problem of excessive viscosity in vegetable oils. The definition of micro emulsion was equilibrium colloidal of optical istropic fluid microstructure with range dimension of 1 to 150 nm. This properties formed spontaneously from two normally immiscible liquids , non ionic or ionic amphiphiles. This properties were usually in oil phase, aqueous phase and surfactant. The limitation maximum viscosity of diesel engine required can be encounter with alcohol (Hussein and Kareem, 2020).

It can be seen on micro-emulsion study by Saravanan in (2012) and the data analyse by taguchi. The outcomes of the analysis were utilised to make required judgements after the experimental data were evaluated using statistical techniques. Because more than one element (injection time, EGR, and injection pressure) were used in this experiment to influence three response variables (NOx, smoke density, and thermal efficiency), the Taguchi technique was used to determine the most influential factor for the selected objective.

2.3.3 Pyrolysis

Pyrolysis known as the conversion of an organic compound to another organic compound by heat in the presences of catalyst. Then, Gebremariam and Marchetti, (2017) state that the product from pryrolysis require further treatment in order to achieve the existing petroleum based fuel. But pyrolysis remain reliable because it still meet notable market

interest. This process consume expensive equipment and it have possibilities to turn into gasoline than diesel.

Futhermore, Devaraj (2015) found that the possibility of utilising waste plastic oil in diesel engines. The waste plastic oil was found to have characteristics comparable to diesel fuel and may be utilised as a diesel replacement. Response Surface Methodology is carried out using Taguchi's L27 Ortagonal Array, which forecasts a 96.08 percent yield.

2.3.4 Transesterification

Transesterification was the most popular and efficient current technology for biodiesel production. The process involve in transesterification of oil with alcohol and produce biodiesel as the main product and glyceride as by product. The technologies transesterification of biodiesel were catalytic and non catalytic transestirification. Transesterification may be used to make biodiesel in a variety of methods. Figure 2.4 shows several various paths of transesterification (Gebremariam & Marchetti, 2017).

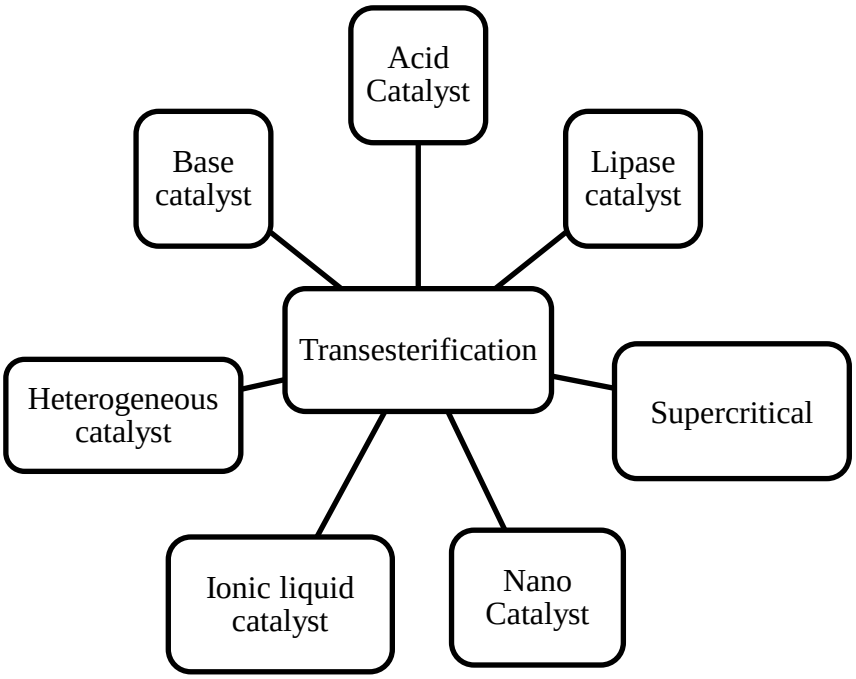

Figure 2.4 Various processes of Transesterification by Gebremariam and Marchetti (2017)

The reaction of a triglyceride (fat or oil) with an alcohol in the presence of a catalyst produces esters and glycerol in all catalytic transesterification processes. A triglyceride is made up of three long-chain fatty acids connected to a glycerin molecule. The type of the fatty acids connected to the glycerin determines the oil or properties fat. The type of the fatty acids can have an impact on the biodiesel properties.

After the reaction period, facile and effective separation of the ester and glycerol layer indicates a successful transesterification process for efficient biodiesel generation. Glycerol, a heavier co-product, can be refined for use in other sectors such as pharmaceuticals and cosmetics (Gebremariam & Marchetti, 2017).

Methanol, ethanol, propanol, butanol, and amyl alcohol are some of the alcohols that can be utilized in the transesterification process as shown in Figure 2.5. Methanol and ethanol are the most often utilized alcohols, with methanol being preferred due to its low

cost and physical and chemical properties (polar and shortest chain alcohol). It reacts fast with triglycerides and dissolves readily in NaOH. A 3:1 molar ratio of alcohol to triglycerides is required to accomplish a transesterification stoichiometrically. In practice, the ratio must be greater to achieve maximal ester production from the equilibrium (Rajalingam, 2016).

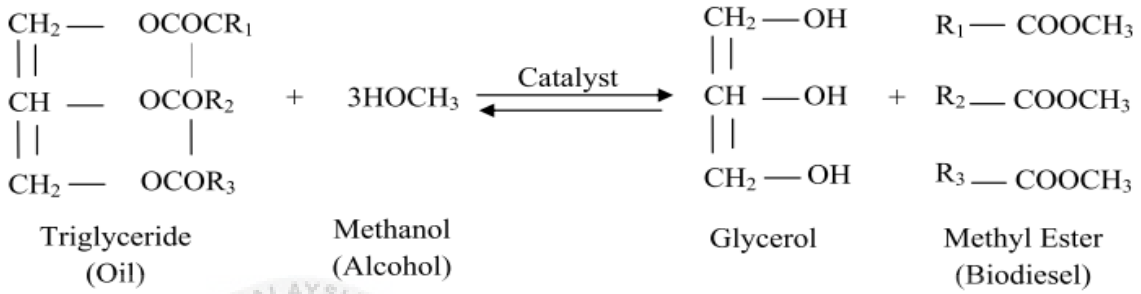

Figure 2.5 Transesterification Reaction. Van Gerpen (2004)

Transesterification is a reversible reaction as shown in the Figure 2.5 that is carried out by mixing the reactants, which is commonly done under heat or pressure. In study conduct by Marchetti in (2017) stated that if a catalyst is introduced to the process, it will be accelerated. The extraction of oil begins with the application of an appropriate temperature, followed by the addition of an alcohol (typically methanol) and a potassium hydroxide catalyst. Babu (2013) also agree that the catalyst will deprotonate methanol, allowing it to attack a triglyceride nucleophilically, resulting in biodiesel (methyl ester) and glycerol as a co-product.

Acid and base catalysts have traditionally been used to conduct heterogeneous and homogeneous transesterification. In homogeneous transesterification processes, alkali catalysts in the form of sodium or potassium hydroxide are more prevalent than acidic catalysts because they give a faster reaction rate. In the case of a high acid content, acid-

catalyzed esterification can also be used to react fatty acids with alcohol to produce biodiesel. The biodiesel con- version can be carried out in the presence or the absence of a catalyst (Moazeni, 2019).

2.4 Catalyst

The transestirification of oil by heating with the alcohol using the catalyst being carried out in this process Two type of catalyst involve homogeneous and heterogeneous catalyst. In order to cut costs, the best method approach will be chosen throughout operation. Figure 2.6 show the common type of Catalyst being used in the production of biodiesel (Taghizade, 2016).

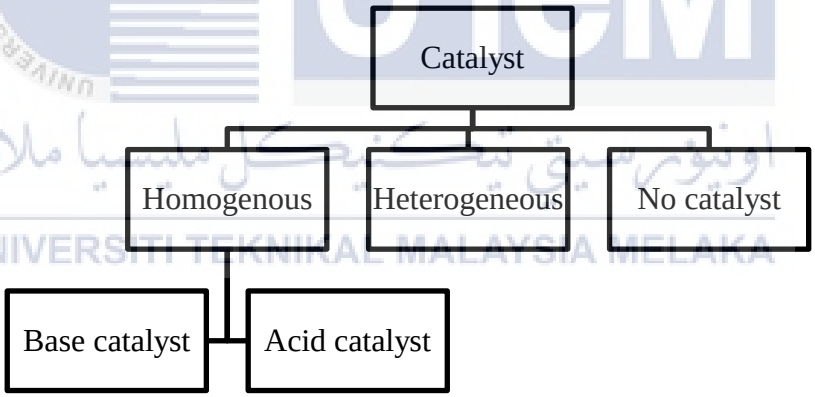

Figure 2.6 Type of Catalyst (Taghizade, 2016)

2.4.1 Homogenous catalyst

The homogeneous catalytic procedures are classified into two categories: homogeneous base catalytic transesterification and homogenous acid catalytic

transesterification (Taghizade, 2016). Because of their high reaction rates, homogeneous base catalysts are widely used in biodiesel manufacturing (Tan, 2016).

2.4.1.1 Base catalyst

This method is currently the most often used in the business sector. Alkaline metal alkoxides and hydroxides, as well as sodium or potassium carbonates, are used as homogeneous catalysts (Taghizade, 2016). This process most used in the sector of commercial. They use homogeneous catalyst such as alkaline metal, alkoxides and hydroxides together with sodium and potassium carbonates.

Method of used methanol for chemical used mostly sodium hydroxide and potassium hydroxide catalyst. Reason behind this catalyst being used because they were the best in operative conditions. In minimum time we can get high conversion rate, this catalyst was economical too (Degfie , 2019).

2.4.1.2 Acid catalyst

In biodiesel production the acid catalyst was used in processing triglycerides. Sulphuric, sulphonic and hydrocloric acid were used as acid catalyst start the process with mixing the acidified alcohol directly with the oil Then, the transesterification separation happe in one step. With the alcohol act as esterification regeant and solvent using ethanol and sulfuric acid, acid catalyzed transesterification was the first process in history to generate biodiesel (ethyl ester) from palm oil (Taghizade, 2016).

The acid catalyzed process is due to the reaction of a triglyceride (fat or oil) with an alcohol in the presence of acid catalyst to form esters (biodiesel) and glycerol. Specially, this method is convenient and economically viable in producing biodiesel from oil or fat resources with high free fatty acid content. However, the acid catalyzed reaction requires a longer reaction time and a higher temperature than the alkali catalyzed reaction (Gebremariam, 2017).

Because transesterification is a balanced reaction, there should always be more alcohol than oil in order to promote the forward reaction and complete the conversion of the oil to alkyl ester. It is also known that the temperature and amount of acid catalyst used in the transesterification process impact the pace of transesterification and the yield of alkyl ester (Marchetti, 2017).

More alcohol than is necessary will result in more costs due to the separation of more generated glycerol from the alkyl ester, which is why the ratio should always be optimized for efficient production. Various experiments one of it done by have been carried out to see how the molar ratio of oil to alcohol to acid, as well as temperature ranges, impact transesterification and alkyl ester production

2.4.2 Heterogeneous Catalyst

Heterogeneous catalyst at in different phases which will help easily preparation method of heterogeneous clasified as one of expensive method. In this method no soap formation will happen two or more division in heterogeneous catalyst can run reactions solid base catalyst more reactive than solid acid catalyst. Most common solid base catalyst was

basic ziolites, alkaline earth metal oxides and hydrtalcites. Solid base also can used heterogeneous catalyst process, which is more reasonable cost production of biodiesel (Gebremariam & Marchetti, 2017).

The heterogeneous catalytic approach allows for a more straightforward purification procedure, which should result in a more efficient and low-cost biodiesel production process. In terms of catalyst regeneration and the ability to be reused in continuous operations, heterogeneous catalysts reduce the issues associated with homogeneous catalysis. According to the literature, the heterogeneous catalytic process has a higher economic potential than the homogeneous one. Heterogeneous catalysts, for example, have 4 to 20 percent lower refining costs than homogeneous catalysts (Tan et al., 2016).

Acid solids that may catalyze the esterification of free fatty acids; base solids that can catalyze the transesterification of triglycerides; and bifunctional solids (acid-base character) that can catalyze both the esterification and transesterification reactions (Alias, Javendra, et al., 2018) For heterogeneous catalyzed processes, different efforts have been undertaken to identify suitable solid catalysts in both acid and basic form (Alias, Javendra, et al., 2018).

2.5 Non Catalyst

Non catalyst method using cenventional transestirification method system. This method usually used to investigate the biodiesel from trygliceride reaction on non catalyst. Non catalyst techniques include supercritical alcohol esterification. Because of simultaneous

transesterification of triglycerides and methyl esterification of fatty acids, a non-catalytic biodiesel production pathway with supercritical methanol has been established, which provides for a simple procedure and high yield (Silva & Oliveira, 2014).

2.6 Production of biodiesel in first, second and third generation of biodiesel

Term of biodiesel come from gas and liquid produced from biomass.Biodiesel commonly being classified into three generations as shown in Figure 2.7 Food crops predominantly the majority of first-generation. Non-edible plant leftovers such as straw, wood, grasses, and other non-edible plant remnants are included in second-generation of biodiesel. Lastly for third generation, consist of microalgae such as seaweed.

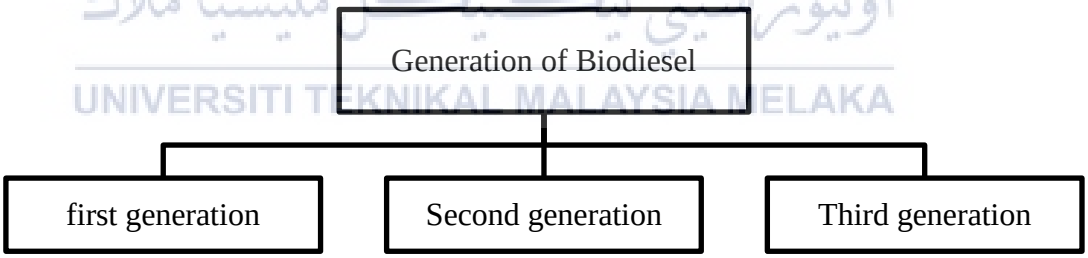

Figure 2.7 Generation of biodiesel (Nanda, 2018)

2.6.1 First generation of Biodiesel

Biodiesel of first generation usually already reach comercial production. They come from food crops. They were mainly from starch,sugar and vegetable oil. This method of production specifically constructed for the purpose of producig energy. So, all the energy

emerge goes into the product. Mostly sugarcane and corn being choosen in the first generation of bioethanol. The leading country that use sugarcane as biodiesel was Brazil. The process of bioethanol sugarcane was simple Sugarcane crushed into the water to remove the sucrose in the sugarcane and purify it to get the ethanol and raw sugar. Eventhough this production give a big impact on the sugarcane bussiness but it effect the pice of sugar that make the increase in price of production of bioethanol also. Other than sugarcane, the corn need to go through preliminary hydrolisis of starch and fermented it to produce ethanol (Nanda, 2018).

In addition to this, Saladini in (2020) stated that the production of ethanol from sugarcane and corn to biodiesel that edible relies upon at the charges dictated via way of means of the worldwide marketplace, while the charges of used cooking oil and jatropha are currently now not influenced into the market industry which is a great incentive for his or her use for biodiesel manufacturing. The availability of such oils is by hook or by crook much less than the classical canola or soybean oil. Moreover, residual cooking oil calls for extra procedures for purification, while manufacturing of jatropha can be constrained via way of means of its low marketplace price which might now no longer be attractive for manufacturing, making it economically feasible simplest on marginal land.

2.6.2 Second generation of Biodiesel

Second generation of biodiesel explore more wide range of source.The focus already on the broader range intonon edible oil also The raw material can be produce from agriculture residue from the forest, biomass or grass. All theses raw material convert into biofuel going through biochemical process. Although, Mofijur in (2021) prove the second

generation use different term which is avoid “fuel versus food” dilema biodiesel of this method consist of two approach. Firstly is thermochemical decomposition including glasification, bio-carbonization, liquefaction and pyrolysis process and the second is biological digestion (Microbia digestion and fermentation). For more than 30 years, biofuel that produced fom lignocellulosic sources have received so much attention. The growing development in this field have reached until commercial stage

2.6.3 Third generation of Biodiesel

Third generation of biodiesel come from source of algae and hydrogen construct from lignocellulosic biomass theresult from the product call as the third generation because they dont occupy the land. Foteinis on (2020) believe that technology of this production use the catalyst to improve and convert the sugar, starch and all form of lignocellulose into short carbon compund that been targeted. Ayhan Demirbas in (2017) also agree about the production of this progress will take medium to long term and need to be considered big scale production

2.7 Biodiesel properties

The necessity of finding the best answer to the global energy problem has increased biodiesel research, development, and production in recent years. We cannot keep relying on crude petroleum as our major source of transportation fuels and power permanently. Furthermore, biodiesel has numerous advantages, including non-toxicity and eco-

friendliness, compatibility with current diesel engines without requiring substantial engine changes, and the ability to use existing diesel engines. Currently, there are a large number of renewable energy sources accessible all over the world (Zahan & Kano, 2018).The quality of biodiesel may also be analyzed via two primary guidelines the American Standard (ASTM Standard) and the European Standard (EN Standard). Based on both standards, Table 2.2 summarises the key characteristics of biodiesel.

Table 2.2 Properties of biodiesel.

Properties	ASTM D6751	EN 14214
Flash Point (°C)	100-170	≥120
Cloud Point (°C)	-3 to -12	-
Pour point (°C)	-15 to -16	-
Kinematic Viscocity at 40(°C)	1.9 to 6.0	3.5 to 5.0
Specific gravity at 15 (°C) (kg/L)	0.88	0.86 to 0.90
Density at 15 ◦C (kg/m³)	820 to 900	860 to 900
Cetane number, min	47	51
Iodine number, max	-	120
Acid number, max (mg KOH/g)	0.50	0.50
Ash (wt %)	0.02	-
Sulphated ash, max % (m/m)	0.02	0.02
Oxidation stability, min (h, 110 ◦C)	3	6
Water and sediment, max (v/v %)	0.05	0.03
Water content, max	0.03 (*v/v*)	500 (mg/kg)
Free glycerol, max (mass %)	0.02	0.02
Total glycerol, max (mass %)	0.24	0.25
Sulphur content, max	0.05%(m/m)	10 mg/kg
Phosphorus content, max	0.001%(m/m)	10 mg/kg
aponification value mg KOH/g	370	-

2.7.1 Standard properties of palm oil biodiesel

Standards are critical for the commercialization and market launch of biodiesel, which is garnering significant worldwide attention and market. Authorities must assess the hazards for user safety and the impact on the environment while providing quality assurance

(Foon, 2017). The European Standard for Biodiesel (EN 14214) and the American Standard Specifications for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels are the two most commonly cited in biodiesel standards (ASTM 6751).

Most of the criteria stated in the US ASTM D6751 are included in the European EN 14214, and the limitations in both standards are the same or extremely similar. Table 2.3 below show the properties of fuel in low pour point and normal palm diesel. The intended applications and suggested test techniques are the most significant variations between these standards (Kumar, 2018).

In accordance with the European Automotive Diesel Standard, the European EN 14214 specifies the requirements and testing procedures for fatty acid methyl esters to be used either as vehicle fuel for engines diesel or as an extender for vehicle fuel for diesel engines (EN 590). The American Society for Testing and Materials (ASTM) D6751 specifies the specifications for biodiesel (100 percent, or B100) for use as a blend component in diesel fuels. The suggested testing techniques are another significant distinction between these standards.

The suggested testing techniques are those provided by the European Committee for Standardization (CEN) and the American Society for Testing and Materials (ASTM). Biodiesel's characteristics are largely determined by the type of its raw material as well as the technique or method used to produce it. The previous standards have defined important requirements to control biodiesel quality in this regard (Foon (2017).

Table 2.3 fuel properties of normal and low pour point palm diesel

Property	Unit	Normal palm diesel	Low pour point palm diesel	EN 14214	ASTM D6751
Ester content	%mass	98.5	98.0 to 99.5	96.5 (min.)	-
Density at 15°C	Kg litre $^{-1}$	0.8783	0.87 to 0.89	0.86 to 0.90	-
Viscosity at 40°C	mm² s^{-1}	4.415	4 to 5	3.5 to 5.0	1.9 to 6.0
Flash point	°C	182	150 to 200	120 (min.)	130 (min)
Cloud point	°C	15.2	-18 to 3	-	Report
Pour point	°C	15	-21 to 0	-	-
Cold filter plugging point	°C	15	-18 to 3	-	-
Sulphur content	%mass	<0.001	<0.001	0.001 (max.)	0.0015 (min) (Grade S15) 0.05 (min) Grade S500)
Carbon residue (on 10% distillation residue	%mass	0.02	0.02 to 0.03	0.3 (max.)	0.05 (max)
Acid value	Mg KOH g^{-1}	0.08	<0.3	0.5 (max.)	0.8 (max)
Sulphate ash content	%mass	<0.01	<0.01	0.02 (max.)	0.02 (max)
Basic sediment and water	%mass	<0.05	<0.05	0.05 (max.)	47 (min)
Cetane number	-	58.3	53.0-59.0	52 (min.)	3 (max)
Copper strip corrosion (3hr, 50°C)	Rating	1	1	1	-
Iodine value	-	52	56 to 83	120 (max.)	-
Content of linoleic acid methyl ester Content of polyunsaturated fatty acid	%mass	<0.5	<0.5	12 (max.)	-
Methyl ester (more than 3 double bond)	%mass	<0.1	<0.1	1 (max.)	-
Methanol content	%mass	<0.2	<0.2	0.2 (max.)	-
Monoglycerides content	%mass	<0.4	<0.4	0.8 (max.)	-
Digelycerides content	%mass	<0.2	<0.2	0.2 (max.)	-
Trygelycerides content	%mass	<0.1	<0.1	0.2 (max.)	-
Free glycerol content	%mass	<0.01	<0.01	0.02 (max.)	0.02 (max)
Total glycerol content	%mass	<0.01	<0.01	0.25 (max.)	0.24 (max)

2.7.1.1 Predicting biodiesel properties by fatty acid methyl ester composition of oil

Both ASTM D 6751 and EN 14214 define procedures for measuring cetane number with a cetane engine, which is a specifically adapted engine for this purpose. Some formulas

link the cetane number to the biodiesel content. In this example, literature data regarding the fatty acid ester content of the fuel utilised in testing the property equation was required (Martin Mittelbach & Martin Mittelbach, Graz, 2006). The cetane number (CN) is a common diesel fuel quality indicator that is linked to ignition delay time and combustion quality. The higher the cetane number, the greater the ignition characteristics are (Meher, 2006). For good engine performance, a high cetane number is necessary. High cetane numbers aid cold start performance and reduce the production of white smoke (Ramos, 2009). The cetane number of biodiesel is widely known to be dependent on the feedstock used in its manufacture. The greater the cetane number, the longer the fatty acid carbon chains are and the more saturated the molecules are (Bajpai and Tyagi, 2006).

According to Knothe on (2003) Low cetane numbers have been linked to higher levels of unsaturation, such as linoleic (C18:2) and linolenic (C18:3) acid esters. Saturated fatty acid esters such as palmitic (C16:0) and stearic (C18:0) acids had high cetane values. Biodiesel made from palm oil is high in these compounds. Researcher, Van Gerpen at year (1996) reported similar findings, seeing an increase in the cetane number as the amount of methyl palmitate in a mix was increased. Because palm oil and palm kernel oil are abundant in saturated fatty acids, the CN of palm oil and palm kernel oil methyl esters in this study is greater than the normal number (>51) (Ramos, 2009).

Regarding to the Iodine value (IV) Lamaisri at year (2015) explain Iodine Value is the measurement of unsaturated fat and oil, higher unsaturation indicate higher iodine value. Standard minimum for IV in Europian standard EN 14214 was 120. The energy content of a fuel is another essential aspect need to be consider. The energy content parameter known as Calorific value (CV) and Heating value (HV). Moreover, Ayhan Demirbas on (2017) also stated that SN and IV acquired from basic chemical analysis may be used to compute the

HV of a vegetable oil. The heating value of a fuel grows as the quantity of carbon atoms in the fuel molecules increases, as does the ratio of carbon and hydrogen atoms to oxygen and nitrogen atoms.

Futhermore, for the density resercher Nguyenthi in (2018) said that the causes of decrease of density come from increase number of atom. Following by that idea, the degree of unsaturation of fatty acid methyl ester is directly related to density, which is inversely proportional to molecular weight.

2.7.2 Acid Value

To determine the acid value of an oil can be find by titrating an oil solution in diethyl ether with an alcoholic solution of sodium or potassium hydroxide It is measured in milligrammes of KOH required to neutralise 1 gram of oil (Dijkstra, 2015). The percent of Free Fatty Acid (FFA) on Equation 2.2 the calculation is to determined on the kind of titrated sample and the fatty acid for which the result is to be calculated. Equation 2.1 can be interprete as KOH in ml the titration value, KOH normality, *N* value is 0.1N, 56.1 is molecular weight of KOH per weight of the oil sample.

$$\text{Acid Value} = \frac{\text{titration x 0.1N x 56.1}}{\text{Weight}} \quad (2.1)$$

$$\%\ \text{Free Fatty Acid (FFA)} = \text{Acid Value x } \frac{1}{2} \quad (2.2)$$

2.7.3 Methanol to oil molar ratio

One of the most important parameters impacting conversion efficiency, output, and cost of biodiesel synthesis is the molar ratio of alcohol to oil. Furthermore, because the stoichiometric molar ratio of alcohol to oil for transesterification is 3:1 and the process is reversible, greater molar ratios are likely to improve miscibility and improve interaction between the alcohol and triglyceride molecules (Musa, 2016).

In 2005, study by Barnwal & Sharma study said that the optimum molar ratio of methanol to oil for alkali-catalyzed transesterification to create biodiesel with more than 98w/t percent yield is around 6:1. As a result, alcohol to oil ratios larger than 6:1 may not enhance yield but may obstruct the glycerol separation process. In the transesterification done by Musa in (2016) procedure, a molar ratio of 6:1 is used to ensure that enough alcohol is present to break the fatty acid-glycerol bonds

2.7.4 Density

Density is the most important biodiesel characteristic that influences fuel quality. Density is a physical quantity that affects all material states, whether they be solid, liquid, or gaseous. It is used in industry to acquire insight into materials, such as their purity, component concentration, and composition. Liquid product density (and concentration) has a significant influence on their quality, behavior, and usage. The determination of density value can be calculate using Equation 2.3.

Diesel engines with a higher fuel density can provide greater power and soot emissions. In the study of Waste cooking oil and castor oil by Pratas in (2011) indicates that at a given concentration, waste cooking oil biodiesel and castor oil biodiesel blends have equal densities. Blends containing up to 70% waste cooking oil biodiesel or castor oil biodiesel can fulfil the density requirements for engine usage under Brazilian or European standards EN 14214. The usage of biodiesel blends with higher density than diesel oil will enrich the fuel/air mixture in a diesel engine with unaltered settings, with the fuel injection system displacing invariable fuel volume quantities (Kannan & Anand, 2011).

$$\rho_{oil} = \frac{\text{mass oil}}{\text{mass water}} \text{ x } \rho \text{ water} \quad (2.3)$$

2.7.5 Reaction Temperature

The impact of temperature on FFA conversion was investigated by varying the reaction temperature between 40, 50, 60, and 70 ℃. In the study made by Karmakar in (2018) identify that maximum FFA conversion was found at 50°C under reaction conditions of reaction duration is 1 hour, catalyst concentration 1% w/t, methanol to oil molar ratio 20:1 and agitation speed 700 rpm. Up to 50 °C there was an increased in FFA conversion of temperature. Any rise in temperature, on the other hand, shows a decrease in FFA conversion.

2.7.6 Reaction Time

In a one-hour reaction time, biodiesel yields were not very high, regardless of catalyst loading levels. After a one-hour reaction, the biodiesel production did rise until it reached its maximum Tan, (2016). Researcher Tan also agree that the optimum time prove by when the reaction duration beyond 2 hours, biodiesel yields remained nearly constant, suggesting that the reaction had achieved equilibrium. Excess reaction time has been found to lower biodiesel production and increase soap formation due to the backward reaction of transesterification.

In addition, on (2006) Leung and Guo agree that the transesterification process for the heterogeneous base catalyst had an optimal reaction time of 2 hours, whereas the homogeneous base catalyst had an optimum reaction time of 1 hour. The conclusion made by Leung and Guo in (2006) showed reaction time was also a determining factor in product yield, and that increasing reaction time had a significant impact on product yield.

2.7.7 Biodiesel Yield

The solubility of biodiesel in methanol was examined. Because methyl esters (biodiesel) were soluble in methanol but triglycerides (animal and vegetable oils and fats) are not, the test was apply to analyse the conversion of oil into diesel Sahar (2018). The methanol were added at the layer of biodiesel and allowed to settle after being agitated for 45 minutes. The unreacted oil has sunk to the bottom, while biodiesel has risen to the top. The unreacted oil was drained off, and the biodiesel was put through a rotary evaporator to remove any liquefy methanol, and the biodiesel yield was estimated using Equation 2.4.

$$\text{Yield} = \frac{\text{Amount of biodiesel produced}}{\text{Amount of Oil sample}} \text{ x } 100 \quad (2.4)$$

2.7.8 Flash Point

Flash point can be define as lowest temperature on which the fuel will produces vapor that enough to cause the ignition that will lead to flame generation. Biodisel flash point was more higher than conventional diesel. In standard also the flash point for biediesel was more higher than diesel standard. The average flash point for biodiesel is 150℃ where when compare with diesel only in the average range of 55℃ to 60℃. The differences of standard flash point related to the component that exist in the fuel.

2.8 Taguchi Method

Method optimization by Taguchi can be interpreted as mathematical techniques apply in the procedure on design or system as functional and effective. Quoting fact by Karna in (2015), he stated that optimization of Taguchi was method to put together all numerical data but in return will be given the maximum risk and minimum risk of analyzation. Process to control some specific parameter set without illicit any constraint. The most trivial target was to minimize the cost and maximize the output and efficiency. This method includes in major tool of quantitative in industrial decision making.

In order to smooth the production system and process design. Boran (2018) also agree about Taguchi that it can be analyze by every unpredictable event and stability system need to be controlled efficiently. The existence of Taguchi method to take control over all the parameter, quality product can be improved and reduced production cost. Parameter design

is a key step in improving product quality and may be thought of as a kind of rigorous design research. There are two types of control factors: controllable and no controllable. In (2019) Manohara and hairnet research together and conclude that Taguchi suggests that the most effective technique to determine the influence of these elements is to use an experimental design. Parameter design, which may be regarded of as a type of rigorous design study, is an important stage in increasing product quality. Control factors are divided into two categories: controllable and no controllable. An experimental design, according to Taguchi, is the most effective method for determining the effects of these components.

The Taguchi parameter design methodology enhances process design by ensuring consistency and robustness of performance. Optimize designs utilizing analytical simulation studies, choose superior alternatives in development and testing, optimize manufacturing process designs, and address manufacturing issues are the key uses of Taguchi methodology. To investigate factor effects and forecast Quality Characteristics, the Taguchi Method uses a standardized orthogonal array experiment design (Karmakar, 2018).

Moreover, In the Taguchi design, an orthogonal array (OA) is a key instrument. It was a subset made up of carefully chosen combinations of many criteria at various levels. The best OA is chosen based on several characteristics and their levels. Rajak (2020) believe An ideal experimental design should deliver the most amount of information with the fewest number of trials possible. Taguchi created orthogonal array triangular tables to minimize the number of experimental trials and improve precision.

2.8.1 Design of experiment (DoE) using Taguchi approach

The design of experiments (DoE) is an effective experimental method for determining the analytical factorial impacts and optimum state in current research. An orthogonal array of statistical experimental design is employed in the taguchi analysis technique to achieve the best output by performing the minimum number of tests; as an outcome, the time and expense of the experiments are saved (Shafiq, 2018).

Futhermore, the study by researcher Kim in (2010) conclude that the main objective of this study is to discover how changes in process parameters impact the mean and variance of parameter characteristics, as well as to identify the factors that make a major contribution. To find the appropriate number of trial experiments, a different orthogonal array design must be chosen depend on the amount of control factors and their levels. Finally, the signal-to-noise (S/N) ratio, Analysis of Variance (ANOVA), and a response table are used to analyse the outcomes of each trial run.

2.8.2 Orthogonal Array

From mathemathical modelling this method statstik apply in the engineering world widely. Researcher Nalbant in (2007) quote that taguchi of orthogonal array proven can reduces experimental number configurations that need to be studied. Moreover in engineering field, numerous data of sample need to identify. The contribution of taguchi method to the world have made the practitioner work more simpler on determine the important parameter and design to make a more clearer understanding on variances and nature of engineering world.

Futhermore, taguchi research done by Cimbala in (2014) quote that depend on how many times you want to test each level of each parameter, you may create Taguchi arrays for the design of experiments. Consider an experiment with three parameters (P = 3 and L = 3) and three levels of each parameter. Taguchi arrays are used in this situation. 6 run array for testing each parameter's level twice 9 run array for three times testing each level of each parameter. Because each level of any one parameter is evaluated, all three levels of the other parameters are also evaluated, the 9 run array is preferable if cost and time allow.

2.8.3 Signal to Noise Ratio

The desirable to non-desirable ratio is known as the S/N ratio. The ideal value found by the optimization procedure is the greatest S/N ratio. The parameters design, also known as robust design, is the most unique aspect of the Taguchi approach. Then, In (2018) researcher kamakar quote that the mean value and standard deviation of the index are commonly interpreted as signal power and noise power. As a result, a system's quality is determined not only by the mean values of the output variables, but also by the system's ability to keep output variability within reasonable parameters without changing its behaviour when component properties vary internally (factors) or externally (environmental conditions) as possible effects of different operating conditions (Freddi and Salmon, 2018).

Possible noise sources in engineering design include manufacturing unit to unit differences, age phenomena such as corrosion, fatigue, ultraviolet degradation, wear, temperature, humidity, and environmental factors, as well as human interface. Equation 2.5 describe how to find signal to noise ratio.

$$\text{Signal to Noise Ratio } = 10 \log_{10} \frac{\text{signal power}}{\text{noise power}} \quad (2.5)$$

i. Smaller is better

When the aim is to reduce the response is picked. Equation 2.6 specifically for the S/N ratio may be thought of as the lower the better.

$$\text{Signal to noise ratio} = -10 \log_{10} \frac{1}{n} \sum yi^2 \quad (2.6)$$

ii. Larger is better

Equation 2.7 it is picked with the intention of getting the most out of the reaction.The S/N is computed with the idea that the higher the number, the better.

$$\text{signal to noise ratio} = -10 \log_{10} \frac{1}{n} \sum \frac{1}{yi^2} \quad (2.7)$$

iii. Nominal is better

Equation 2.8 is selected when the goal is to intend the response and the S/N must be based only on the standard deviation. Smaller is better when it comes to S/N.

$$\text{signal to noise ratio} = -10 \log_{10} \frac{1}{n} \sum (y_1 - y_{0)^2} \quad (2.8)$$

2.9 Analysis of Varience (ANOVA)

In the 1920's Sir R.A Fisher develop the statistics measurement called Analysis of Variance (ANOVA). The "design experiment" was the book produce by fisher that gain worldwide acknowledgement. In educational research, usage of ANOVA first applies in 1934 and until world war 2 the usage of ANOVA accelerated rapidly. By the year of 1960's the usage of ANOVA become common use in experimental and educational purpose. Research about history of ANOVA by Tweney in (2014) stated that in 1960's also the application of ANOVA in Doctorate research become an obligation required course.

Moreover, on the last decade of twenty centuries, there has been a wider recognition of the formal similarities between ANOVA and multiple linear regression techniques, both of which are applications of a generalized. The ANOVA is used to determine which process parameters have a significant impact on performance attributes. This is performed by dividing the total number. The square division total sum SS_T can be calculated by this equation (2.10) below.

$$SS_T = \sum_{i-1}^{n} y_i - C.F. \tag{2.9}$$

The n in this experiment taken from the orthogonal array and y_i was the reduction of ith in the experiment and C.F. was the factor of correction. The calculation of C.F. can use the equation (2.10) and T was the sum of total reduction.

$$C.F. = \frac{T^2}{n} \tag{2.10}$$

Deviation square of total sum can be decomposed from two sources, SD due to each parameter error and the error of sum square was SS_e , the sum of square error, is caused by parameter process each. The percentage contribution, *P*, of each process parameter to the total sum of square deviation, SS_T, was calculated as a ratio of each process parameter's sum of square deviation, SS_d to the total sum of square deviation, SS_T. F-ratios (variance ratio) was a statistical test for determining whether characteristics have significant effects on the quality characteristic of a plastic tray. The mean of square deviation, *SSm*, attributable to each process parameter must be computed before the test to *F* can be performed.

2.10 Literature Review matrix

Table 2.3 matrix of literature review is based on the previous researcher finding the various biodiesel production. The analysis from the review will effect on the decision to make the most optimum result based on the comparison listed. This literature review totally helpful to organize the journal to be as a references during experiment conduct.

Table 2.4 Matrix of Literature Review

Researcher	Method of produce	Method of Optimization	Type of Oil	Parameter					Yield%
				Catalyst concentration	Me: OH	Catalyst	Reaction Time	Temperature	
(Mohadesi et al., 2019)	Microreactor	-	WCO	1%	9:1	KOH	120 s	60°C	95.24
	Microreactor	-	WCO	1%	9:1	KOH	120 s	60°C	97.12
	Microreactor	-	WCO	1%	9:1	KOH	120 s	60°C	96.33
(Lam et al., 2010)	Conventional	-	WCO	1%	9:1	KOH	2 h	87°C	87
(Tan et al., 2016)	Conventional	Taguchi	WCO	0.75%	6:1	KOH	2 h	65°C	97
(Degfie et al., 2019)(Silva & Oliveira, 2014)	Thermal decomposition method	Taguchi	WCO	1%	8:1	CaO nano-catalyst	90 min	50°C	96
(Gebremariam & Marchetti, 2017)	Microwave	-	WCO	0.75%	6:1	CH3ONa	3 min	microwave power of 750 W	97.90
	Conventional	-	WFO	3 %	12:1	Tetramethyl	150 min	65°C	>90
(Muhammad FArooq a, 2013)	Two-Step Catalyzed Process	-	WCO	1.2%	6:1	KOH	60 min	40°C	98.32
(Karmakar et al., 2018a)	Esterification	-	Castor oil	1%	20:1	Sulfonated carbon	60 min	50°C	90.83
(Phan and Phan 2008)	Acid-catalyzed process	-	WCO	0.75%	8:1	KOH	80 min	50°C	88-90
(Encinar et al. 2007)	Conventional	Taguchi	WCO	1%	12:1	KOH	120 min	50°C	94.5
(Mohamad et al., 2017)	Microwave	-	WCO	0.7%	55:1	KOH	6 min	55°C	96.49
(Sahar et al., 2018)	One-step transesterification process.	-	WCO	3%	15:1	Ca2+	3 h	80°C	92.1
(Gupta & Rathod, 2018)	Hammett indicator	-	WCO	1.5%	10:1	Eggshell	50 min	60°C	96.07
(Gupta & Rathod, 2018)	Microwave	-	WCO	3.99%	2.9:1	Coal fly ash	60 min	66.20°C	94.91
(Buasri et al., 2014)	Conventional	Taguchi	Scallop waste shell	10%	9:1	CaO	3 h	65°C	95.44
(Hsiao et al., 2020)	Microwave	-	WCO	4%	8:1	CaO	75 min	65°C	98.2
(Gaur et al., 2020)(Mohadesi et al., 2020)	Ultra sound	-	WCO	0.46%	6.1:1	KOH	-	53.2 °C	97.76
	Micro Reactor	-	WCO	1.16%	9.4:1	KOH	2 min	62.4 °C	98.26
(Ulfah et al., 2019)	Two-stage reaction	-	WCO	1%	1.5:1	sulfated alumina	60 min	60 °C.	90.4 %

CHAPTER 3

METHODOLOGY

3.1 Introduction

The accepted properties of biodiesel determined by the proportion of fatty ester, heating, reaction time, reaction temperature, catalyst and alcohol concentration. In the process to get optimize result every unit and sample need to be identify carefully from handling until safety precaution. Researcher Zhang, (2003) quote that the process simulation is a useful method for predicting process characteristics and their relationships with design and operating variables in this regard. Simulations of biodiesel from Hamza in (2015) do the processes that have been done before. Separation factors from a single experiment may no longer be relevant when considering different scales of process design since the ratios of the various components in the streams are no longer the same. This can result in a low yield of biodiesel or a product of poor quality.

The method to determine the optimization using taguchi method. To find the most optimum the best properties of biodiesel that run with many sample and repetitive data study show that, Taguchi's technique was chosen for optimizing variables such as reaction temperature, reactant proportion, and purification methods done by researcher Gemma in (2006) investigated sunflower oil biodiesel production and come out with an optimization technique. The method of taguchi being implement on this study was Method L9 (3^2) orthogonal array. Which is interprete as 16 run of sample with 3 trial each and 4 parameter .

3.2 Methodology

The accepted production of biodiesel can be divide into four phases: raw material preparation transesterification and washing as shown in Figure 3.1.

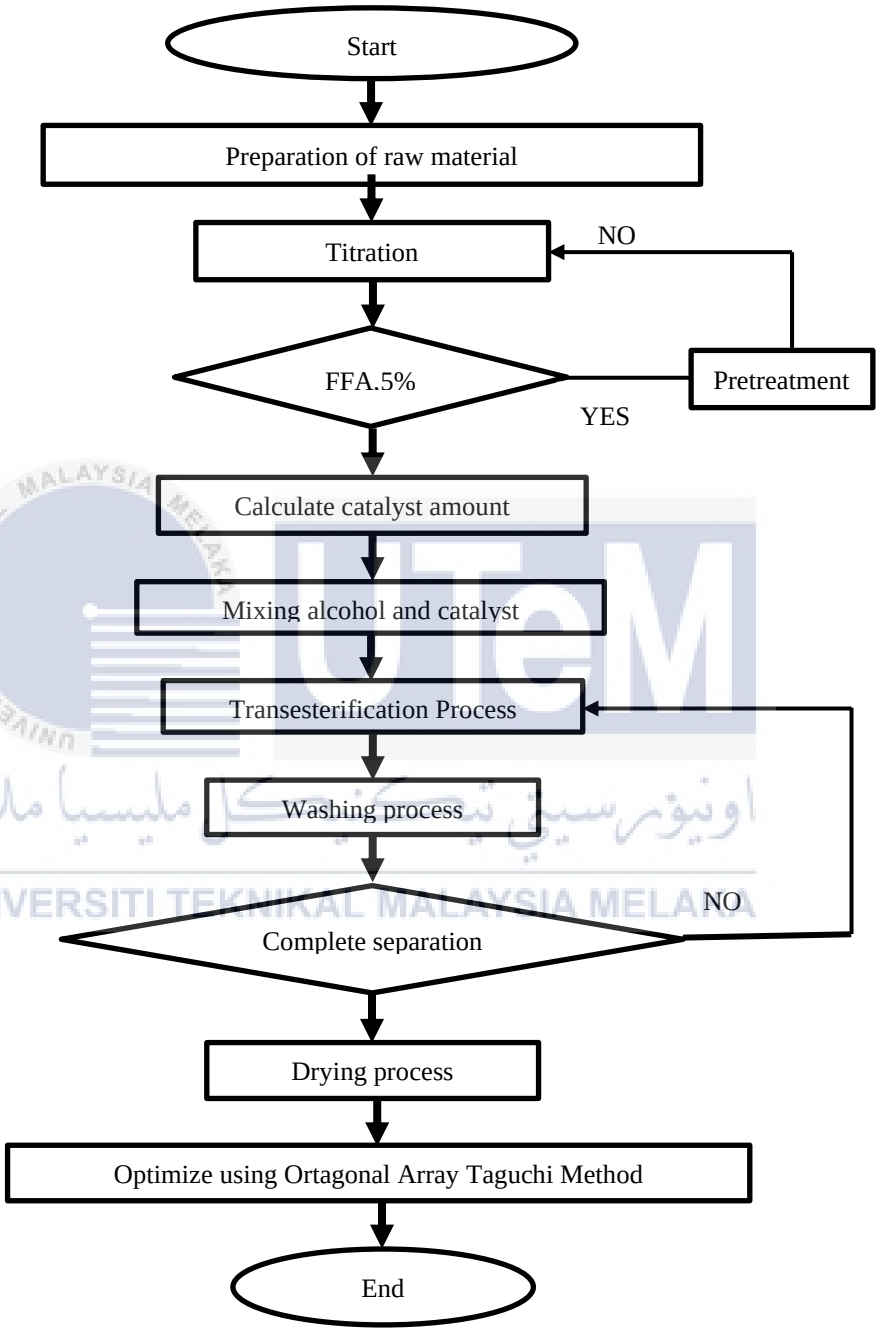

Figure 3.1 Process Flow Chart of Biodiesel Production

3.2.1 Experimental Setup

The procedure of this laboratory experiment Figure 3.2 follow the national standard procedure ASTM D6751 to produce biodiesel and being supervise with competent personel such as laboratory technician for safety guidance.

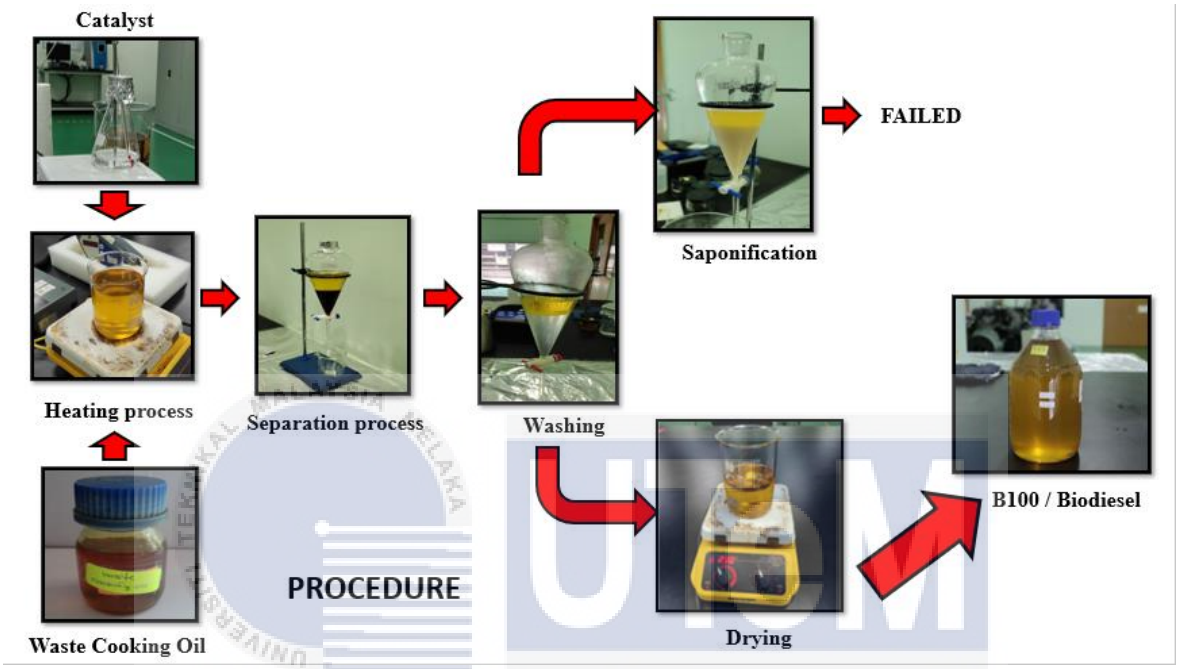

Figure 3.2 Biodiesel production procedure

3.2.2 Material

Raw waste cooking oil collected from various industry and dump together. The first sample of waste cooking oil was from domestic household. 5 kilogram of waste cooking oil sources from frying french fries two time and another 5 kilogram sources from frying groundnut and chicken. The mix of 10 kilogram waste cooking oil dump together to get the same value of acid value throughout the laboratory experiment. Raw waste cooking oil filtered before dump into the same container to filtered small particles and substances.

3.2.3 Determination of Acid Value

To prepare for the acid value we need 5 gram of oil weighed and put in the beaker. Isopropyl alcohol 25 millilitre in measuring cylinder. This two liquid mix together with added 2-3 drop of phenolphthelein. The solution of potassium hydroxide (KOH) have been prepare beforehand. Firstly, 5.61 gram solid potassium weight and light crush in the mortar and mix with 1 litre of distilled water. The solid potassium mix together with 1 Litre of distilled water will make a new solution called potassium hydroxide that can be used 4 month from the date of manufacture. The titration will take place to get the number of acid value. When the solution turn into purple-ish colour, Figure 3.3 below show the slight colour change on solution from titration process. After the colour change immediately pull the solution from KOH titration.

Figure 3.3 Solution colour change from titration process

3.2.4 Transesterification

Based on the molar ratio, calculate the weight of methanol needed and the catalyst also prepare followed by the percent needed. The methanol and catalyst mix together in the flask. The methanol heated on the hot plate with 50 °C temperature and catalyst heated on the plate with range of 60°C to 65°C. Then, 200 gram sample of raw being taken and heated on the hot plate with temperature not more than 65°C. The purpose of this step was to remove excess water on the oil. The solution of methanol+catalyst mix with raw oil and heated until 90 minutes. Throughout the heating process, aluminium foil being used to cover the top of the beaker in order to prevent the methanol evaporate into the air The temperature of this solution mixture can not exceed 70° C. After the solution being heated about 90 minutes. The solution put in the separation funnel to undergone transesterification process overnight.

3.2.5 Washing and drying

After being leave overnight, methanol at the top of the separation funnel suck out by pipettes. 200 ml of distilled water heated with the range temperature 65° C to 70° C and the heated distilled water mix with the biodiesel in the separation funnel and shake it he fat on the bottom surface of the separation funnel being drain into the beaker.The washing process (Shake the biodiesel with water), repeat 4-5 times or until the ph value 7. Failed sample will not going through separation process and will become soap Biodiesel oil with ph value 7 pour into the beaker and heated on the hot plate with temperature exceed 110 °C and wait 90.

3.2.6 Flash Point Testing

The testing of flash point being done in lab oil and analysis UTeM. The equipment name was Pensky-Marten closed cup flash point tester. Importantly, the handling of this laboratory equipment need to be under technician laboratory. When handling high temperature item all safety procedure need to be follow and need to wear gloves when moving the hot cup after heating the sample.

Firstly, the sample of oil put on the flash point cup until the line inside the cup. Then, the lid closed, and put the stirrer with 250 rpm setting. Spark a small flame toward the burner and wait until the temperature hit 100 °C. After that, the temperature controlled increase 2 °C per minute. When the temperature more than 100 °C the lid needed to be open and closed slowly until the flash point achieved. Toward this experiment the flame need to be always analyze closely. Lastly, when the ignition sources cause the distinct flash the temperature will be recorded.

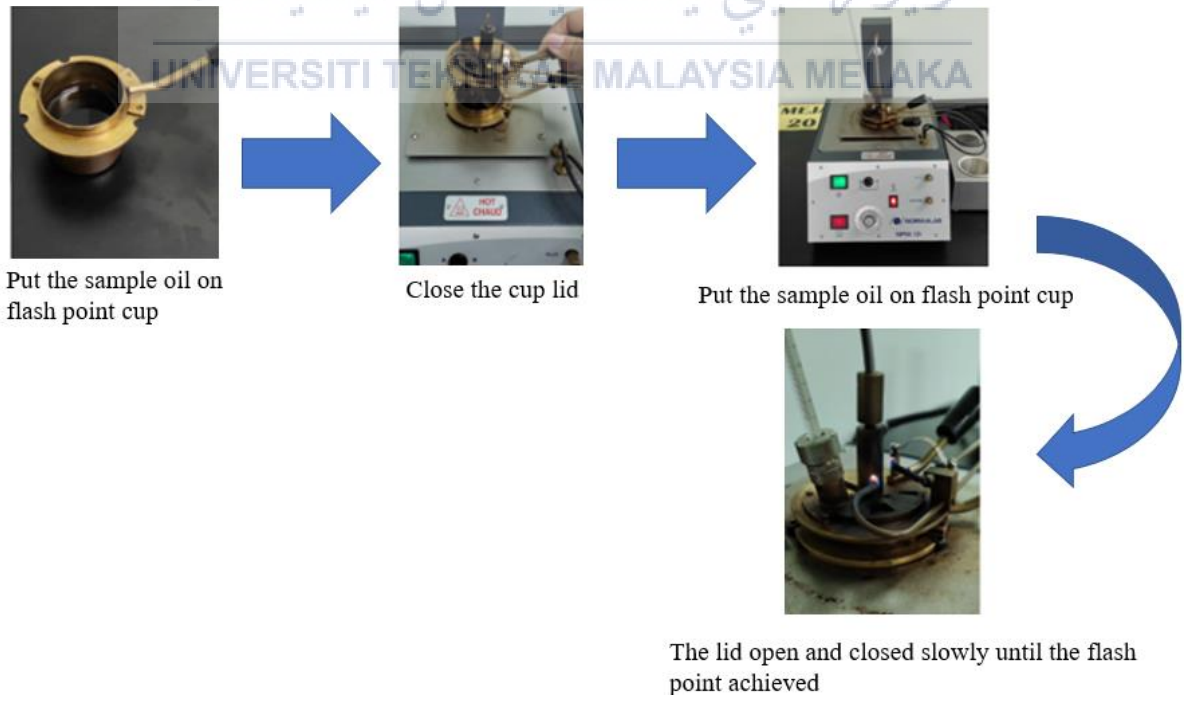

Figure 3.4 Flash Point Procedure

3.2.7 Gas Chromatography Mass Spectrometry (GCMS)

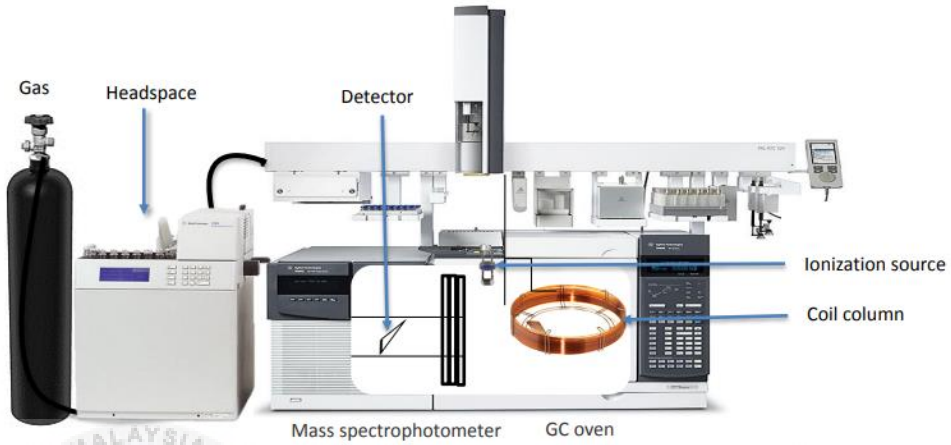

Figure 3.5 GC-MS Equipment (Harvey, 2004)

Chromatography was widely used as a vital technique for analysing, separating, and purifying components from complicated mixtures. Separation and purification of proteins, carbohydrates, amino acids, vitamins, secondary metabolic chemicals in plants, and food quality assurance are all examples of how chromatography is used in technology development. Futhermore, GCMS was one of the instrument that can allow component of individual to separate into an essential oil according to the mass and votality. With the help of trained chemist the analyzing need to be done under competent supervision. Because the trained chemist can identify wether the oil pure or not and can interprete the composition in the oil. As for now, GCMS still well known as the "gold standard" to determine the chemical properties of the oil.

Firstly the basic procedure on how to operate GCMS, the trained chemist will put the sample on injection port. Then, the sample oil will vaporize through the coil column with the help of inert carrier gas. The coil column will provide a surface for the compound to

interact. It will allow the component to slow down so, the separation can occur. When the vaporized sample oil pass through the coil column, the oven temperature will increases. Moreover, when the compound reach end of column, it will hit the detector. The peaks of each chemical component will recorded on the chromatogram.

After the molecule pass through the column coil, they will hit electron volt which can cause the molecule to break. The break molecule will form positive cations. Beside, the ion will travel through electromagnetic field that will filter them into their mass. Other than that, the detector will amplify and count each number of ion associated with specific mass. The information will be send to computer where mass spectrum created. The spectrum will show every individual component on sample.

3.2.8 Result of Gas Chromatography Mass Spectrometry (GCMS)

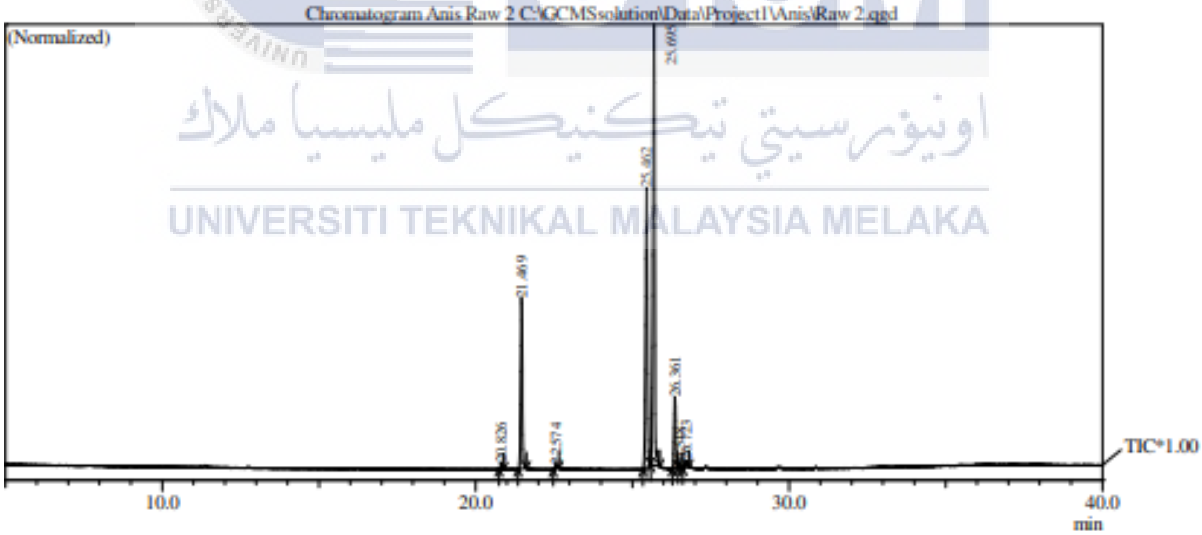

Figure 3.6 Spectrum analysis graph of GCMS

Table 3.1 Peak Report of GCMS

Peak	R.Time	I.Time	F.Time	Area	Area%	Height	Height %	A/H
1	20.826	20.750	20.900	1733180	0.62	499372	0.70	3.47
2	21.469	21.358	21.625	45568579	16.38	12493209	17.46	3.65
3	22.574	22.475	22.667	1609454	0.58	337024	0.47	4.76
4	25.462	25.342	25.575	80267401	28.86	20371399	28.47	3.94
5	25.695	25.583	25.875	127156093	45.71	32127333	44.90	3.96
6	26.361	26.275	26.450	19509667	7.01	5191733	7.26	3.75
7	26.518	26.467	26.617	258102	0.09	67481	0.09	3.74
8	26.723	26.617	26.808	2066471	0.74	457694	0.64	4.50
				278168947	100.00	71545245	100.00	

Result from GCMS was in a form of spectrum analysis. The time it takes for analytes to transit through the column and reach the mass spectrometer detector is usually shown on the x-axis of a gas chromatogram. The times at which each of the components arrived at the detector are represented by the peaks. The retention period is greatly influenced by the kind of column used in the analysis, as well as the GC parameters. As a result, it's vital to utilize the same settings when comparing retention periods from different tests or labs to assure accuracy.

The area of the peak, or the y-axis, is usually a reflection of the amount of a given analyte present. The area of a GC/MS chromatogram is determined by the number of counts collected by the mass spectrometer detector at the site of retention. It's worth noting that some compounds have a higher affinity for the detector, causing the peaks to appear larger than they are in respect to the other peaks on the chromatogram, which is common with ionizing substances. To address this issue, our specialists use standards with known component concentrations to assure accurate counts. Unknown chemicals are also discovered using various detectors based on their retention periods of established standards. The mass spectrometer detector then enables for compound identification using the mass spectrum recorded during testing.

3.3 Application of Taguchi method optimization

A statistical technique was utilized in this experiment design to examine the influence of different parameters include in the study and to identify their ideal sequences. The Taguchi technique of experiment design use a set of orthogonal arrays to do the fewest possible experiments. To put it another way, the Taguchi approach entails to determine a great number of experimental scenarios, refer as orthogonal arrays, Table 3.1 was a Taguchi orthogonal array that have been identified to be used in this experimental analysis. Furthermore, to reduce errors and improve experiment efficiency and reproducibility. Orthogonal arrays are a set of numerical tables that can be used to quickly achieve optimal experimental designs by considering a variety of scenarios.

Table 3.2 OA used to design experiments with two parameters at three levels, L9 (3^2)

Taguchi, P = 2, L =3			
Run #	Methanol to Oil molar ratio	Catalyst	*X*
1	1	1	X1
2	1	2	X2
3	1	3	X3
4	2	1	X4
5	2	2	X5
6	2	3	X6
7	3	1	X7
8	3	2	X8
9	3	3	X9

The design of orthogonal array was being used to evaluate the effects of two parameters on the production of waste cooking oil biodiesel, including the molar ratio of alcohol to oil, catalyst type, catalyst concentration, and reaction temperature, using an experimental design methodology based on the Taguchi approach. The primary operating

characteristics and levels were derived from previously published research by Kim on (2010).

It is possible to derive or search up Taguchi arrays. Large arrays can be derived via deterministic algorithms; small arrays can be sketched out manually. Arrays may usually be available on the internet. The amount of parameters (variables) and levels determine which arrays are used (states). This is addressed in greater detail later in this article. The acquired data from the Taguchi design of trials can be utilised to pick new parameter values for optimising the performance characteristic using analysis of variance. Plotting the data and doing a visual analysis, ANOVA, bin yield and Fisher's exact test,

Table 3.3 OA used to design experiments with two parameters at three-levels, L9 (3^2)

Experiment No	Parameter and their level	
	Molar ratio (oil/methanol)	Catalyst concentration (wt %)
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3

In addition to above table 3.2, two parameters chosen at three level L9 (3^2). All the factor diversity will be studied by cross the orthogonal array-controlled parameter. Moreover, in this study, Minitab19, which was the software that used to determine the automatic analysis and design of Taguchi. Minitab19 will optimize and analyze all the sample data. The optimize result will produce from the setting control variable.

3.3.1 Taguchi Method Review

Taguchi used to improve the product quality and product processes. Quality of the improved result on the higher level can be obtain. The possible of the highest performance can be determine by the combination of optimum design factor. The product/process is made insensitive to the influence of the uncontrollable element to achieve consistency of performance. The best design is identified using design of principle experiment, and consistency of performance is attained by accomplish trial assessment under the noise factor effect, according to Taguchi's technique.

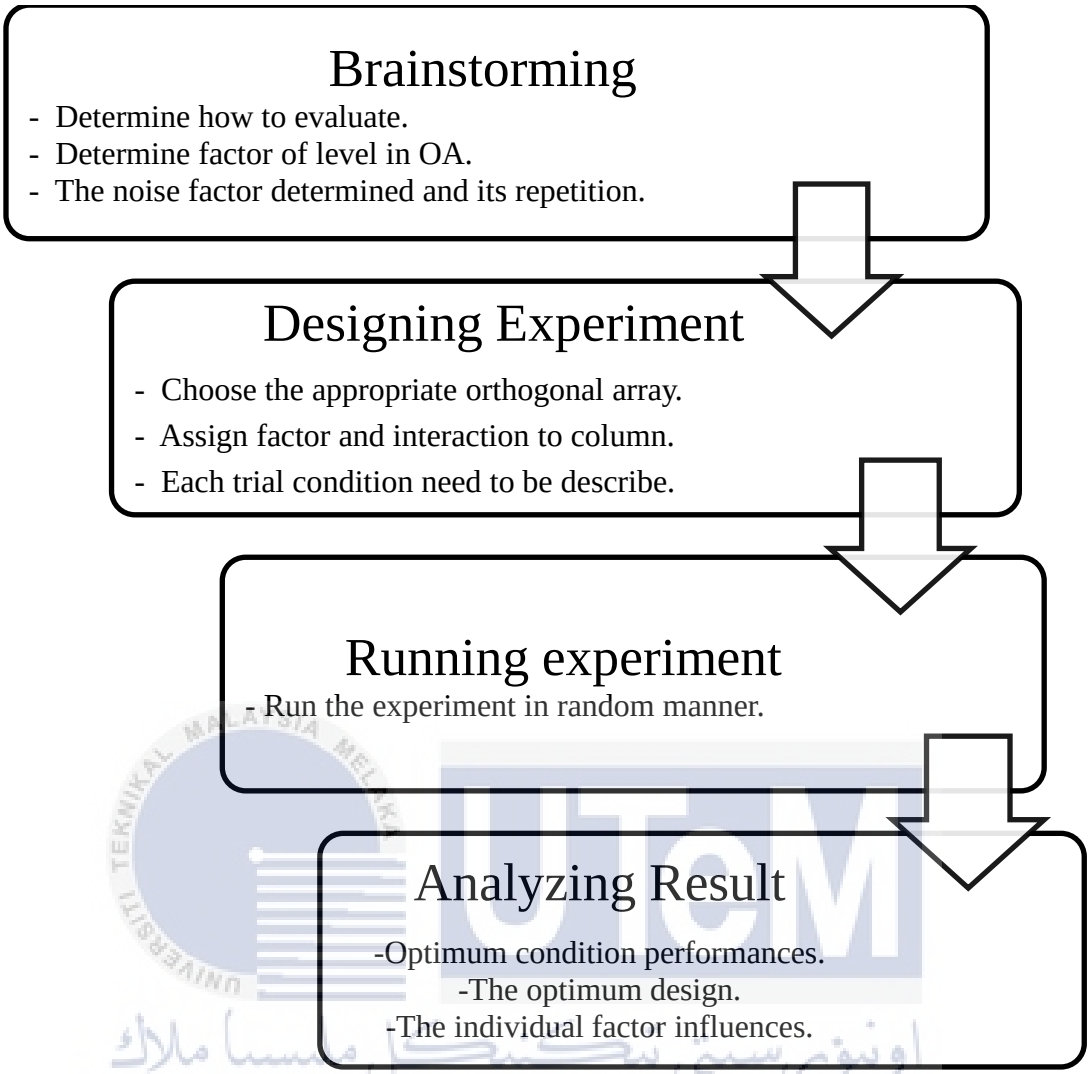

Figure 3.1 Phases in Taguchi Experimental.

3.4 Analysis of variance (ANOVA)

Simple mathematical operations are used to calculate result averages and factor-level effect averages, which provide answers to important problems that were unconfirmed in the project's earlier stages. However, based on quote state by Singh and Verma in (2019) only analysis of variance can answer questions about the influence of factors on the variation of findings in terms of discrete percentage. You'll learn how to compute all analysis of variance

terms in this phase. Review a few examples of analysis in this step to gain confidence in interpreting the experimental results.

Moreover, researcher Samir Kumar on (2009) also agree that the ANOVA test allows you to investigate inconsistencies in your data set by analyzing the numerous elements that influence it. These techniques are used by analysts to produce extra data that was more compatible with model of regressions. A 'null hypothesis' occurs when there was no significant difference between the two group that being tested, and the F-ratio of the ANOVA test should be near to 1.

Mostly on cases of ANOVA, the data and calculation can be run on excel software. However, you may do an ANOVA test by manually by following the table 2.4 of standard below.

Table 3.4 ANOVA standard output

Sources of variation	Sums of square (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-value distributions
Between treatment	$SSB = \sum n_j \ (\bar{X}_j - \bar{X})^2$	k-1	$MSB = \frac{SSB}{k-1}$	$= \frac{MSB}{MSE}$
Error or residual	$SSE = (X - \bar{X}_j)^2$	N-k	$MSE = \frac{MSE}{N-k}$	
Total	$SST = \sum\sum(X - \bar{X})^2$	N-1		

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will present the result based on study objectives. Quantitative data collected and analyse using taguchi method to get the best optimizations. High temperature, high pressure, and a high alcohol to oil molar ratio are all required for high transesterification yields, according to research. Other then that Silva and Oliveira in (2014) do state that high temperature and pressure do, in fact, necessitate a large initial investment (equipment expenses) in order to execute such operations and safety management policies.

Futhermore, researcher Degfie in (2019) agree that because an increase in the oil to alcohol molar ratio should allow increased contact between substrates, encouraging reaction conversion, it is one of the most critical factors impacting the yield of fatty acid esters in the transesterification technique. Because several chemical events such as hydrolysis, polymerization, oxidation, and material transfer between oil and food occur during the frying process, the chemical and physical features of the oil are altered.

The use of biodiesel in conventional diesel engines reduces unburned hydrocarbons, carbon monoxide, and particulate matter significantly. Biodiesel is a clean fuel since it has nearly little sulphur, no aromatics, and around 10% built-in oxygen, which allows it to burn completely. Even when mixed with petroleum diesel, its greater cetane number enhances ignition quality. Biodiesel is different from the vegetable and waste oils used to fuel converted diesel engines since it is designed to be utilised in conventional diesel engines.

Biodiesel can be used on its own or in combination with petrodiesel. Biodiesel can also be used to replace heating oil as a low-carbon option.

4.2 Result and discussion

Overall of the study aiming for the optimization of biodiesel using taguchi method. The method will give result of the most optimum parameter of biodiesel. Untreated waste cooking oil is one of the sources that contribute to pollution. As a result, making biodiesel from used cooking oil is the greatest option, and more research on waste cooking oil characterisation is needed. The research provide a good gather all community in more appreciating environment and living life and not easily throw the waste everywhere. One of the most important variable in biodiesel yield was the molar ratio of alcohol and oil. The best optimization will make us moving more forward to replace the non renewable energy fuel. Before the start of experiment, data of waste cooking oil recorded in the table to make the comparison after producing pure biodiesel.

Table 4.1 Properties of Raw WCO

Raw WCO	Unit	Standard measure	Result
Acid Value	Mg/KOH	ASTM D664	4.26
FFA	%		2.13
Density	Kg/m^3	ASTM D6751	894
Colour	-	-	Dark brownish-black

4.2.1 Waste cooking oil analysis result

Sample of 5 milliliter waste cooking oil sample send to material characterization laboratory in University Putra Malaysia (UPM), Serdang as shown in the Figure 4.1 the sample number 2 was the sample of waste cooking oil and sample 1 was jatropha curcas oil.

Figure 4.1 5 ml of waste cooking oil in bottle sample number 2

The waste cooking oil properties need to be analyse before transesterification reaction process. The data result collected from experimental in laboratory Factory 4 UTeM about a month duration to complete the taguchi table. The outcome result of the molecular weight of waste cooking oil sample that send to UPM was 848.07 g/mol and the density of the oil was 894 kg/m^3. The density and flash point of the biodiesel oil was done in the oil and wear lab on factory 3 UTeM. The flash point obtain by using pensky marten flash point tester.

4.3 Taguchi optimization experimental table

Table 4.2 Raw experimental result

Run	Methanol to molar ratio	Catalyst (wt %)	Reaction time(min)	Reaction temperature (℃)	Yield(%)	Acid Value(mg /KOH)	FFA(%)	Weight(g)		Density (kg/m³)	Flash Point >130
								Before	After		
1	6:1	1.5	90	65	Failed	0	0	200	0	0	-
2		2.0			79.35%	0.2244	0.1122		158.7	837.89	186
3		2.5			60.65%	0.2244	0.1122		121.3	837.28	-
4		3.0			54.87%	0.3366	0.1683		109.74	836.69	-
5	9:1	1.5			75.24%	0.1122	0.0561		150.48	844.08	184
6		2.0			72.79%	0.2244	0.1122		145.57	840.48	-
7		2.5			69.07%	0.3366	0.1683		138.13	840.49	-
8		3.0			27.37%	0.4488	0.2244		54.74	-	-
9	12:1	1.5			60.15%	0.4488	0.2244		120.31	-	-
10		2.0			55.36%	0.4488	0.2244		110.71	-	-
11		2.5			68.93%	0.2244	0.1122		137.86	838.89	190
12		3.0			Failed	0	0		0	-	-
13	15:1	1.5			81.50%	0.3366	0.1683		163.24	845.03	-
14		2.0			65.22%	0.2244	0.1122		130.44	834.89	-
15		2.5			66.58%	0.2244	0.1122		133.15	837.49	-
16		3.0			Failed	0	0		0	0	-

The experimental of raw data followed Taguchi L16 (3^2) to minimize sample of experiment data. From Table 4.2 above, 16 sample being produces. Three sample failed on separation process. Molar ratio 6:1 with catalyst 1.5 wt% failed to even separated after leaving the sample overnight.and the other two failed sample 12:1 and 15:1 using high catalyst 3 wt%.

4.3.1 Taguchi Orthogonal Array L9 (3^2)

The process of selection Taguchi Orthogonal Array for the experiment must followed the total degree of freedom that need to be computed. Once the degree of freedom known, and the next step was selected the suitable OA. In this study, As seen from Table 4.3. an L9 OA was applied. This array used two different parameter that will be include in mintab19 software and two constant parameter that not included. For each level two paramater will be tested. Overall nine run of success experiment choosen to include in table of Taguchi. The result generate by minitab show that the molar ratio 9:1, catalyst 1.5 give the best value of optimizations.

Table 4.3 Orthogonal Array Experimental Result

Run	Me:OH	Catalyst(%)	Reaction time(min)	Reaction temperature(°C)	Yield(%)
1	9:1	1.5	90	65	75.24
2		2.0			72.79
3		2.5			69.07
4	12:1	1.5			60.15
5		2.0			55.36
6		2.5			68.93
7	15:1	1.5			81.50
8		2.0			65.22
9		2.5			66.58

4.3.2 Analysis of Variance Signal to Noise Ratio.

Overall Analysis of signal to noise ratio generate by minitab19 software. Table 4.4 and Table 4.5 was table generate from Taguchi Orthogonal Array. The sum square of SS_T and SS_e clarify as one-way ANOVA and it is use to create the mean square. From the mean square, F value will be generate and using F-distribution table the value of P can be achieved.

Table 4.4 Analysis of Variance (ANOVA) for WCO

Sources	DOF	SS	MS	F-ratio	P-value
Methanol to oil molar ratio (SS_f)	2	3.873	1.9364	2.47	0.200
Catalyst Loading (SS_f)	2	1.521	0.7606	0.97	0.453
Error (SSe)	4	3.134	0.7834		
Total (SS_T)	8	8.528			

Table 4.5 ANOVA for Percent Contribution

Parameters	Symbol	Rank	Level			Differences			Contribution (%)
			1	2	3	L2-1	L3-1	L3-2	
Molar ratio	A	1	37.18	35.72	37.02	-1.46	-0.16	1.3	69.15
Catalyst loading	B	2	37.11	36.11	36.69	-1	-0.42	0.58	30.85

In table 4.5, Percentage Contribution (P) that influence the most in this study were Methanol to oil molar ratio with (69.15%) and followed by second high influence catalyst loading (30.85%). Because of that Methanol to oil molar ratio rank no 1 of factor that influences the experiment and catalyst loading rank no.2. From the table 4.5, SN Ratio for molar ratio give the highest number on level 1 which is 37.18. The value implicate the maximum yield of biodiesel. Then, observation on P-value of the factor give the number more than 1. The P-value that exceed more than 1 indicate that the probability will be higher than 100%. In this case the null hypothesis can be rejected in statistical analysis when the probability more than 1.

Futhermore, Degree of Freedom (DOF) indicate the amount of information in data given. DOF will give the informantion about the unknown parameter population. Total of DOF was the number of observation being made in the overall sample, which is the total is 8. The Degree of Freedom will increase if the size of the parameter or population increases. If the number of term in the sample increase, the model can use more information to analyze.

Which will decrease the available paramter to be identify. Continously, the mean square can be determine by dividing the sum of square with the degree of freedom.

Moreover, reaction of the molar ratio strongly influence the most. At the beginning, reaction molar ratio of 6:1 with catalyst 3 wt% failed going through transesterifications because of the small number of molar ratio methanol to oil. The presence of catalyst cannot separate the glycerol and oil. Sample of catalyst 3% even have high number of acid value because it was not compatible with the molar ratio. The 2 wt% of catalyst among all the sample give the most number of yield. Further increase of the catalyst loading above the 3 wt% will failed the transesterification if not increase in the molar ratio number methanol to oil.

As the reaction time fixed to be 90 minutes , stated the research by Leung and Guo in (2006) the reaction time was also decisive factor in product yield, and that increasing reaction time had a significant impact on product yield and for homogenous it should not exceed 2 hours.

Table 4.6 Response Table for FAME WCO

FAME	Methanol to Oil molar ratio	Catalyst loading (wt % of oil)	Reaction time (min)	Reaction temperature (°C)	Yield (%)	Predicted yield (%)
	A	B				
WCO	9:1	1.5	90	65	75.24	76.333

Waste cooking oil response table 4.6 show the predicted yield by Minitab was 76.333% and the yield during the experiment 75.24% not far from the predicted yield.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

By employing waste cooking oil as a feedstock, the cost of biodiesel may be decreased. The amount of fatty acids in waste cooking oil might be decreased by pretreating it with an acid catalyst. Water generated during the esterification process can function as an inhibitor of the acid catalyst, which can be overcome via a stepwise reaction mechanism. (Gnanaprakasam, 2013). The current study primarily focused on identifying key factors that have a substantial impact on FFA conversion and optimising the esterification process using the Taguchi method. The WCO acquired from local places is used as a feedstock for the production of biodiesel at a low cost (Dhawane, 2018).

Biodiesel is proven better than the petrodiesel that come from fossil fuel. Biodiesel was the best option to replace the petrol diesel. Evenmore nowadays, Malaysian diesel already mix with the biodiesel in order to slowly replace the non-renewable energy. The more production and research ongoing on biodiesel, the more it will contribute to the world environment and will lower the cost production of biodiesel. The recent development of technologies already improve the way to produce biodiesel in short time and get the result follow the standard guideline by ASTM D6751 nad EN 14214.

We can conclude the objective of this research the production of biodiesel from waste cooking oil follow the guideline standard by ASTM D6751 and EN14214. The acid value of the most optimize sample was significantly below than 0.5 which is 0.1. Moreover, the flash

point of the all biodiesel sample proven can exceed 130 °C temperature. Certainly, the usage of Taguchi Method to optimize the parameter of molar ratio methanol to oil, reaction time, reaction temperature, and catalyst was the most efficient way to sort the big data sample. Signal to noise ratio larger is better was used to identify the imporatnce of the parameter and interprete it in statitics way. Primarily, the Analysis of Variances (ANOVA) give the result of percent contribution of the parameter among all the sample. This way, the data sample can be narrow down more to the important of the data sample.

The Taguchi approach proved effective in determining the best combinations. With a predicted yield of 76.333% and an experimental yield of 75.24%, Taguchi's parameter design techniques predictions was good in order to confirm the significant of the data result. Biodiesel produce from waste cooking oil was economical and friendly because it was renewable energy.

5.2 Recommendations

Recommendation on using fully biodiesel to replace the petroldiesel because the research of the biodiesel has been wider more year to come. New idea and stratergies to commercialize the usage of biodiesel need to be develop. Eventhough, more challenges will need to be face in order to implement the usage of biodiesel 100% in the society. The awareness of Malaysian society to recycle the waste cooking oil need to enhanced in order to protect our environment from untreated substances that can bring harm in the long time. Law and mandate need to implemented in the society for everyone to not throw away the waste cooking oil especially on the sewarage. The conversion of waste cooking oil into biodiesel will benefit to all living thing and protect environment.

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APPENDIX

Appendix 1 : Molar ratio calculations

Pre-treated Waste Cooking Oil = 848.07(g/mol) x 1 mol
= 848.07 g

Molecular Weight of methanol = 32.04 (g/mol) x 1 mol
= 32.04 g

Ratio

9:1

$$= \frac{9 \text{ x } 32.04 \text{ g}}{1 \text{ x } 848.07 \text{ g}}$$

= 0.3400 x 200 g

= 68 g

12:1

$$= \frac{12 \text{ x } 32.04 \text{ g}}{1 \text{ x } 848.07 \text{ g}}$$

= 0.4534 x 200 g

=91 g

15:1

$$= \frac{15 \text{ x } 32.04 \text{ g}}{1 \text{ x } 848.07 \text{ g}}$$

=0.5667 x 200 g

= 113 g

Appendix 2 : Catalyst concentration (wt %) calculations.

1.5 wt %

$= \frac{1.5}{100}$ x 200

=3g

2.0 wt %

$= \frac{2.0}{100}$ x 200

2.5 wt %

$= \frac{2.5}{100}$ x 200

Appendix 3 : Calculation of Density

Appendix 3 : Density Calculations

Detail	Mass
Empty pychnometer	27.62 g
WCO oil + pychnometer	69.9 g
Distilled water + pychnometer	77.56 g

Mass of WCO

69.9 g – 27.62 g = 42.28 g

Mass of Distilled water

77.56 g – 27.62 g = 49.94 g

Density of oil

$\rho_{oil} = \frac{0.4228}{0.4994} \times 997$

= 844.08 kg/m³

Appendix 4 : Gantt Chart

Gantt Chart Bachelor Degree Project II												
Activity	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12
Project Discussion	4/10/21-8/10/21											
Sending sample		11/10/21-15/11/21										
Analyze sample data GC-MS			18/11/21-22/11/21									
Preparation of making the production				25/11/21-29/11/21								
Production Of Sample Biodiesel					29/11/21-10/12/21							
Analyze the optimum sample by Taguchi							13/12/21-25/12/21					
Direct Blend									27/12/21-1/1/22			
Complete chapter 4 and 5										1/1/22-11/1/22		

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: OPTIMIZATION OF BIODIESEL PRODUCTION FROM WASTE COOKING OIL USING TAGUCHI METHOD.

SESI PENGAJIAN: **2021/22 Semester 1**

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Pensyarah
Jabatan Teknologi Kejuruteraan Mekanikal
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
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