OPTIMIZATION OF BIODIESEL PRODUCTION FROM THE WASTE COOKING OIL USING RESPONSE SURFACE METHOD

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in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Optimization of Biodiesel Production From The Waste Cooking Oil Using Response Surface Method" is the result of my own work except as cited in the references.

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal Fluid).

Signature :. ....

Name of Supervisor : MD ISA BIN ALI

Date : ....

ABSTRACT

Biodiesel is one of the renewable energy sources. Commonly, biodiesel is made from the vegetable oils and animal fats. The advantages of using biodiesel are it can reduce pollution and petroleum consumption. Waste cooking oil (WCO) is one type of feed stocks that can be used to convert into biodiesel by using transesterification process. In order to optimize the biodiesel production, Response Surface Method (RSM) from Minitab 16 has been used. This project is to ensure that petroleum supplies not run out and to reduce environmental effect at water and soil that come from WCO. The objectives of this project are to determine the empirical equation of biodiesel production and to optimize yield production with related to catalyst concentration, reaction temperature and methanol to oil molar ratio. Magnetic stirrers and digital analytical balance are types of apparatus that has been used in this experiment. The experimental results, shows that the maximum yield production that can be extracted from WCO is 82.6% by using 60 °C of reaction temperature, 0.8 wt. % catalyst concentrations and 10:1 methanol to oil molar ratio. By using Minitab 16 to optimize the experimental results, it shows that 59.5 °C reaction temperature, 9.8:1 methanol to oil molar ratio and 0.74-0.92 wt. % catalyst concentration must be used to get yield percentage more than 80%.

ABSTRAK

Biodiesel merupakan salah satu sumber tenaga yang boleh diperbaharui. Biasanya, biodiesel diperbuat daripada minyak sayur-sayuran dan lemak haiwan. Kelebihan menggunakan biodiesel adalah ia dapat mengurangkan pencemaran dan penggunaan petroleum. Sisa minyak masak (WCO) adalah salah satu jenis stok makanan yang boleh digunakan untuk menghasilkan biodiesel dengan menggunakan proses transesterifikasi. Dalam usaha untuk mengoptimumkan pengeluaran biodiesel, Kaedah Sambutan Permukaan (RSM) dari Minitab 16 telah digunakan. Projek ini bertujuan untuk memastikan bahawa bekalan petroleum mencukupi untuk tempoh yang lebih panjang dan untuk mengurangkan kesan alam sekitar ke atas air dan tanah yang disebabkan oleh WCO. Selain itu, objektif projek ini adalah untuk menentukan persamaan empirikal pengeluaran biodiesel dan untuk mengoptimumkan pengeluaran hasil yang berkaitan dengan kepekatan pemangkin, suhu tindak balas dan nisbah molar di antara methanol dan WCO. Pengacau magnetik dan penimbang digital analitik merupakan alatan yang telah digunakan dalam eksperimen ini. Keputusan eksperimen menunjukkan pengeluaran hasil yang maksimum yang boleh diambil dari WCO adalah sebanyak 82.6% dengan menggunakan suhu tindak balas 60 °C, kepekatan pemangkin 0.8% berat dan nisbah molar untuk methanol dan WCO adalah 10:1. Dengan menggunakan Minitab 16 untuk mengoptimumkan keputusan eksperimen dan ia menunjukkan bahawa suhu tindak balas setinggi 59.5 °C, nisbah molar untuk metanol dan WCO adalah 9.8:1 dan kepekatan pemangkin 0.74-0.92% berat mesti digunakan untuk mendapatkan peratusan hasil lebih daripada 80%.

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WCO	Waste Cooking Oil
UTeM	Universiti Teknikal Malaysia Melaka
RSM	Response Surface Method
NaOH	Sodium Hydroxide
KOH	Potassium Hydroxide
LCD	Liquid Crystal Display
CCRD	Central Composite Rotatable Design
FFA	Free Fatty Acid
PSM	Projek Sarjana Muda

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Non-renewable energy is a source that will not be replenished. Coal, petroleum and natural gas are an example of non-renewable energy sources. Usually, petroleum is a part of the chemical makeup of many plastics or synthetics and mostly used to power internal combustion engines. Nowadays, renewable energy such as solar energy and biofuels need to take place in industries to ensure that the petroleum sources not completely depleted for next generation.

In Figure 1.1, United States Energy Information Administration shows that about 92% of the energy consumed in the United States comes from non-renewable energy sources where dominated by petroleum with 37%. Thus, for the remaining 8% of renewable energy then divided into 7 components where biofuels comes to the second runner up as renewable energy source with 22% from all 7 components. In order to make sure the petroleum resources not extinct for future, the consumption of petroleum in industries need to be reduced.

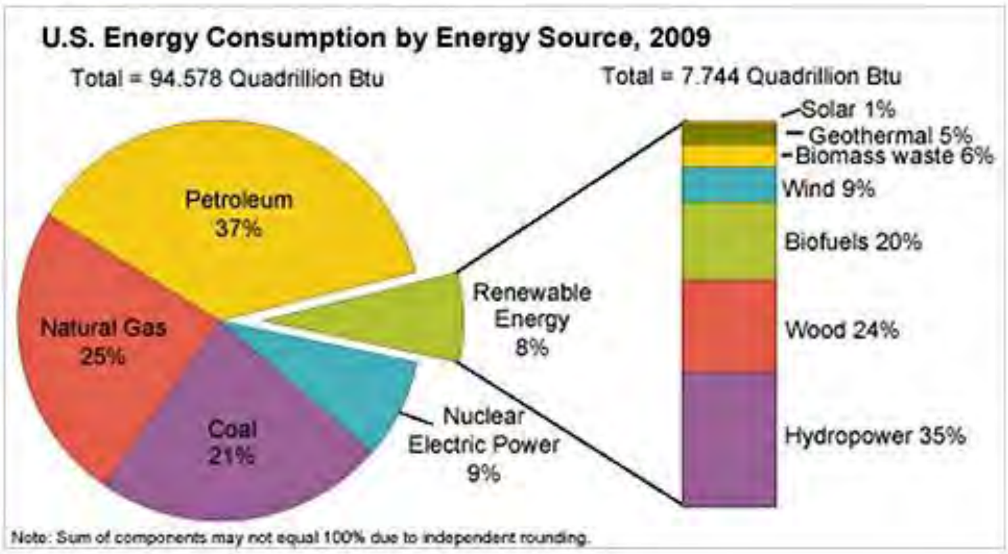

Figure 1.1: U.S. Energy Consumption by Energy Source, 2009

(Source: Nancy Folbre, 2011)

For renewable energy, biofuels is a good alternative to power internal combustion engine rather than solar energy because solar system is not the best option to apply in industries. The disadvantages of solar power are the initial cost for purchasing and installing a solar system is expensive. Besides that, it uses a lot of space and stop producing electricity when sun goes down or is heavily shaded (Abhishek Shah, 2011).

Biofuels are divided into two categories that are widely used globally, which are bioethanol and biodiesel. Commonly, biodiesel is made from the vegetable oils and animal fats while bioethanol is made from fermented sugar (CheHafizan and Noor Zainon Zainura, 2013). The advantages of using biofuels are it can reduce pollution and petroleum consumption. The potential for reduction of greenhouse gasses is significant because biofuels are biodegradable and not harmful when released in the environment.

Biodiesel consists of long chain mono-alkyl esters and do not contain sulphur or aromatics compound in its composition because of hydrocarbon chains. Biodiesel is an alternative fuel that is being appreciated all over the world because it is environmentally friendly, agriculture oriented, non-toxic and renewable fuel. Furthermore, it can also be blended with other energy sources, has a high cetane number, low volatility and presence of oxygen atoms in the fuel molecule (Demshemino et. al., 2013).

Biodiesel is having some properties similar or slightly higher than fossil diesel in term of density, viscosity, flash point, cetane number and heating value. Density of biodiesel is slightly higher than the fossil diesel and it will decreases as the temperature increases. Moreover, biodiesel is easy in the transportation due to high flash point and it also depends on the types of feedstock to have the same or high kinematic viscosity. In addition, it also has higher cetane number and less heating value (Sayyed et. al., 2013). In order to produce a biodiesel from vegetable oils or animal fats, transesterification process must be used to reduce the viscosity of the product.

Transesterification is a process to convert the animal fats and vegetables oils into a biodiesel. This process involves a mixture of alcohol, catalyst and raw material. Several operating parameters such as alcohol to oil molar ratio, catalyst concentration and reaction temperature must be considered to obtain a quality biodiesel in terms of yield production percentage. In 2008, Malaysia produced 17.7 million tons of palm oil on 4.5 million hectares of land and became the largest exporter of palm oil in the world (Nor Hazwani Abdullah et. al., 2013). Palm oil will become a main feedstock to produces biodiesel because the most cooking oil in Malaysia is made from palm oil.

Commonly, Response Surface Method (RSM) is used to optimize of biodiesel production in fats and oils feedstock. To illustrate with three dimensional plots, RSM must be presenting the response in function of two factors and keeping the other constant. Other than that, it will shows the effects of the main operating parameters including the alcohol to oil molar ratio, catalyst concentration and reaction temperature on the biodiesel yield.

1.2 PROBLEM STATEMENT

Petroleum is a non-renewable energy and the supplies will run out or will not be replenished. Mostly, in industries and social systems is based on oil because it has high energy density, low cost, also easy for extracting and transport due to its liquid form (Abhishek Shah, 2011). Biodiesel is an alternative energy to change the current energy and it can be done by converting waste cooking oil (WCO) into biodiesel.

Waste from cooking oil can give harmful effect to the environmental such as water and soil. It happened because people nowadays do not care about pollution effect and do not realize the benefit of recycling the waste. A preliminary survey was conducted among the community of Teluk Bahang Penang, Malaysia and it shows approximately 400 kg to 500 kg of WCO was produced by the 30 participants monthly (Hanisah, 2013). Mostly, the participants just discarded the WCO into dustbin, soil and drainage system.

The survey shows that the unconcerned of people about the useful of WCO. WCO can be converted into biodiesel by using transesterification process. This process is used to reduce the viscosity of the product. In order to optimize the biodiesel production, Response Surface Method can be used to determine the empirical equation and to optimize the yield production with related to catalyst concentration, reaction temperature and methanol to oil molar ratio.

1.3 OBJECTIVE

1. To determine the empirical equation of biodiesel production.
2. To optimize the yield production with related to catalyst concentration and reaction temperature.
3. To optimize the yield production with related to catalyst concentration and methanol to oil molar ratio.

1.4 SCOPE OF PROJECT

1. To study the process of transesterification by using WCO as feedstock. This process is used to get methyl ester from the WCO and use it as a biodiesel. All samples in this process will use different of catalyst concentration, methanol to oil molar ratio and reaction temperature with constant stir and time.
2. To investigate the effects of the main operating parameters, including the methanol to oil molar ratio, catalyst concentration and reaction temperature on the biodiesel yield by using Response Surface Methodology (RSM) base on a certain design. RSM will optimize the production of biodiesel and presenting the response with three dimensional plots.

CHAPTER 2

LITERATURE REVIEW

2.1 WASTE COOKING OIL (WCO)

2.1.1 Feed Stocks of WCO

A material that contains fatty acids can be used to produce biodiesel. Thus, vegetable fats, vegetable oils, animal fats, waste greases and edible oil processing waste can be used as feed stocks for biodiesel production. The choice of feedstock is based on local availability, government support, cost and performance as a fuel. Commonly, biodiesel producer will choose vegetable oils and animal fats as a primary feedstock. Table 2.1 shows the countries and feed stocks around the world.

Table 2.1: The Countries and Feed Stocks around the World

No	Country	Raw product or feedstock
1.	Mexico	Animal fat, waste oil
2.	Canada	Canola oil, animal fat
3.	USA	Soybean oil, waste oil
4.	Brazil	Soybean oil, palm oil, castor oil, cotton oil
5.	Spain	Sunflower oil
6.	France	Rapeseed oil, sunflower oil
7.	UK	Rapeseed oil, waste oil
8.	Sweden	Rapeseed oil
9.	Finland	Rapeseed oil, animal fat
10.	Germany	Rapeseed oil
11.	Italy	Rapeseed oil
12.	India	Jatropha oil, karanja oil, mahua oil
13.	China	Jatropha oil, waste oil
14.	Thailand	Palm oil, jatropha oil, coconut oil
15.	Malaysia	Palm oil
16.	Indonesia	Palm oil, jatropha oil
17.	Russia	Rapeseed oil, soybean oil, sunflower oil
18.	Japan	Waste oil
19.	Korea	Waste oil
20.	Philippine	Coconut oil, jatropha oil
21.	Australia	Waste oil, animal fat
22.	New Zealand	Waste oil, animal fat

(Source: Sayyed Siraj et. al., 2013)

Malaysia produced 17.7 million tons of palm oil on 4.5 million hectares of land and Malaysia has become the second largest exporter of palm oil in the world (Szmigielski et. al., 2008). In order to manage the large scale of palm oil land, Malaysia was hiring employee more than 570,000 people (Chhetri et. al., 2008). Mostly, about 40% of palm oil in Malaysia was used as cooking oil, margarine, specialty fats and oleo chemicals (Szmigielski et. al., 2008). In the fast food business, a single branch can produce more than 15 litres of WCO per day (Nor Hazwani, 2013).

2.1.2 Properties of WCO

There are many different values of properties between unused cooking oil and used cooking oil. Table 2.2 shows the physicochemical properties of used and unused cooking oil. The used cooking oil samples were collected from the cafeteria in Universiti Teknologi PETRONAS. The spectroscopic analysis was performed for the used and unused cooking oil samples (Zahoor Ullah et. al., 2014). There is no significance spectroscopic and structural changes occurred for used and unused oil samples after the comparison of the data has been made.

Table 2.2: Physicochemical Properties of Used and Unused Cooking Oil

No	Properties	Unused Cooking Oil Values	Used Cooking Oil Values	Units
1.	Acid value	0.3	4.03	mg KOH/gm
2.	Calorific value		39658	J/gm
3.	Saponification value	194	177.97	mg KOH/gm
4.	Peroxide value	< 10	10	meq/kg
5.	Density	0.898	0.9013	gm/cm^3
6.	Kinematic viscosity	39.994	44.956	mm^2/s
7.	Dynamic viscosity	35.920	40.519	mpa.s
8.	Flash point	161 to 164	222 to 224	°C
9.	Moisture content	0.101	0.140	wt.%

(Source: Zahoor Ullah et. al., 2014)

2.2 BIODIESEL

2.2.1 Properties of Biodiesel

To ensure the engine operate properly and prevent the damage on the engine component, the usage of fuel in the engine system must be similar to the standard given. Biodiesel must be able to full fill the entire standard prescribed before it can be used as a fuel in the engine system. The chemical and physical properties of biodiesel will be slightly different because it depends on the type of feed stocks used to produce biodiesel. Table 2.3 shows the selected properties of typical no. 2 diesel and biodiesel

Table 2.3: Properties of Typical No. 2 Diesel and Biodiesel

No	Properties	Diesel	Biodiesel	Units
1.	Fuel Standard	ASTM D975	ASTM D6751	
2.	Lower heating value	~129,050	~118,170	Btu/gal
3.	Kinematic viscosity @ 40 °C	1.3 to 4.1	1.9 to 6.0	mm^2/s
4.	Specific gravity @ 60 °C	0.85	0.88	kg/l
5.	Density	7.079	7.328	lb/gal
6.	Water and sediment	0.05 max	0.05 max	% volume
7.	Carbon	87	77	wt.%
8.	Oxygen	0	11	
9.	Sulphur	0.0015	0.0 to 0.0024	wt.%
10.	Boiling point	180 to 340	315 to 350	°C
11.	Flash point	60 to 80	130 to 170	°C
12.	Cloud point	-15 to 5	-3 to 12	°C
13.	Pour point	-35 to -15	-15 to 10	°C
14.	Cetane number	40 to 55	47 to 65	

(Source: U.S Department of Energy. Biodiesel Handling and Use Guidelines, 2006)

2.2.2 Advantages of Biodiesel

Biodiesel is a renewable energy sources that can give more advantages to the future. Biodiesel is not like fossil fuel that can run out anytime because biodiesel come from manure, corn, switch grass, soya beans, waste from corps and plants. Besides, the rate price of biodiesel is same with petroleum in the market but biodiesel produce less gas carbon emissions on burning compared to the petroleum. Mostly, biodiesel can perform very well in current engine designs and keep the engine running for longer (Jared, 2012).

In addition, biodiesel can reduce the impact of greenhouse gases up to 65 percent and global warming. Greenhouse is the phenomena where the gas likes carbon dioxide trapping sunlight and cause planet to warm, while global warming is happen because of the increasing in temperature that is come from burning of the coal and oil. Lastly, biodiesel can keep economy secure because a country can reduce its dependence on fossil fuels. It also can reduce the number of unemployed because more jobs will be created with growing biodiesel industries (Jared, 2012).

2.2.3 Disadvantages of Biodiesel

The cost production of biodiesel is quite high in the current market because the interest and capital investment being put into biodiesel production. After that, biodiesel is made up from waste from crop but planting same crop every year may deprive the soil of nutrients. Fertilizer will be used to grow crops better but it can cause water pollution because fertilizers contain nitrogen and phosphorus. One major problem when using biodiesel is it can rise in food prices because of the pressure on