ABSTRACT

Biodiesel can be defined as a substitute for diesel fuel which is derived from vegetable oil or animal fat. In this project, fabricate, design and commission a mini plant that produces biodiesel from used cooking oil (UCO). The highlight of this research is the introduction of the Gingerize concepts during the first step catalyzed process. Transesterification reaction is a reaction between oil or fat with alcohol in the presence of strong base catalyst to produce methylester (biodiesel) and glycerol. Transesterification reaction is conducted at an optimum condition of 60°C reaction temperature, 30 minutes reaction time and 400 rpm stirring. This reaction uses sodium hydroxide, (NaOH) as the second catalyst and methanol, (MeOH) as the alcohol. The yielding quantity of 15 liters plus the reactant result in generating 13 liters of biodiesel which is equivalent to 90% production efficiency. 10% glycerol produce can be used for other purposes. The product density and combustion are analysed. The result shows that the density of the product is in a reasonable agreement with ASTM 6751 and the product B100 combusted vigorously in a 3:1 low compression spark ignition engine (Alternative Fuel Engine (AFE)).

Keywords: Biodiesel, gingerize, used cooking oil, transesterification, ASTM 6751, AFE
1.0 INTRODUCTION

Nowadays the world is facing a crucial limited amount of crude oil for fuel because the decreased in stocks. It is important to replace the fossil fuel for a new alternative fuel. Biodiesel is one of the renewable fuels that considered being efficient and safe for the environment. The benefit of using biodiesel is also clear and unquestionable. Biodiesel which is relatively clean – burning, renewable fuel produced from new and used animal and vegetable oil (Canakci, 2007). Production of biodiesel could be blended with portion of fossil diesel and thus can reduce the ultimate used of the latter. Biodiesel is not a petroleum – based fuel, which means by using biodiesel would reduce the usage of the natural fuel. It is also produce domestically, which means that using biodiesel will also create jobs opportunity and contribute to the local and country economies. The major advantage of biodiesel is that biodiesel is much cleaner than the conventional diesel; it produces less harmful emissions that the fossil diesel when burned in a combustion engine. This alternative fuels gives a lot of advantages towards all living things and creatures.

Most typical biodiesel feedstock (palm oil, soybean, peanut, olive oil and beef tallow) cost is substantially greater than the cost of the petroleum diesel. Therefore, alternative feedstock is being evaluated to identify less expensive materials that could serve as feedstock for biodiesel production. One of the most promising biodiesel feedstock is UCO. This is due to the fact that it is in favour of the environment and economic as it is readily available as waste materials from restaurants and households. However, UCO contain dirt, charred food, contaminants and also have high free fatty acid (FFA) content. Thus, the oil is subjected to pre-treatment process which is odour removal and filtration prior to processing into B100.

Biodiesel is non-petroleum based alternative diesel fuel that consists of alkyl esters derived from renewable feed stocks such as plant oils or animal fat. Biodiesel is alkyl esters made from chemically reacting vegetable oil or animal fat and alcohol in a catalysed reaction process called transesterification. Oil or fat contains triglycerides. Triglyceride is an ester derived from glycerol and three fatty acids as shown in Figure 1.
Vegetable oils used for cooking or frying generally display a higher degree of saturation, higher viscosity, higher cloud and pour points, higher cetane numbers as well a greater oxidative stability can be expected from biodiesel fuels derived from these feedstock (Gerhard & Kevin, 2009). As UCO has unpleasant odour, to remove the bad smell by using ginger and also act as initial catalyst. The two –step catalyzed process will provides a simple and economic method to produce biodiesel from UCO (Monge, Scheline, & Solheim, 1976). Properties of ginger produce Zingerone,\( (C_{11}H_{14}O_{3}) \) also called vanillylacetone, is a key component of the pungency of *ginger*. (P. Kumaran, Nur Mazlini, Ibrahim Hussein, M. Nazrain & M. Khairul, 2011). Zingerone is a crystalline solid that is sparingly soluble in water, but soluble in ether [5]. Fresh ginger does not contain zingerone; cooking the ginger will transforms to gingerol (Yong Wang, Shiyi Ou, Pengzhan Liu & Zhisen Zhang, 2007).

In this work, a new gingerize process concept being adopted for the production of biodiesel. The first Two-stage process is by frying the slices ginger together with fine filtered UCO to remove the unpleasant odour and also was introduced to catalyze the esterification reaction. During the second step, sodium hydroxide, \((NaOH)\) as the second catalyst reacted with methanol, \((MeOH)\). Resulted product will be analyzed its density and combusted inside a Megatech Mark III Alternative Fuel Spark Ignition Engine (SI).
2.0 METHODS

There are three main parts of this studies, firstly; design, fabricate and commissioning of Mini Plant. Secondly; production of UCO B100 biodiesel which will includes the availability of feedstock and the two-stage process. Lastly the analysis of UCO B100 density and the engine test on Megatech Mark III Alternative Fuel SI Engine.

2.1 Part 1 : Fabrication

The capacity of 15 litres Mini Plant being fabricated and took 6 months to finish. Starting from designing the plant, fabrication takes quite sometimes to finish as certain design need to be modified during the process. Figure 2 shows the schematic diagram of Mini Plant which consists of main components such as Gingerize reactor, transesterification mixer and washing components. The solid model of the plant as shown in Figure 2.
2.2 Part 2 : Process

2.2.1 Materials

The samples of UCO were provided by a local restaurant, then being fine-filtered to remove all the coarse contaminants. Local planted ginger or ginger root sliced to 3-5 mm thickness.

![Completed Mini Plant](image)

*Figure 3: Completed Mini Plant*

2.2.2 First step catalyzed and odour removal process - Gingerize process

Frying ginger will produce gingerol with molecular formula $C_{17}H_{26}O_4$ and molar mass 294.38 g/mol. Cooking the ginger will transform gingerol into zingerone. Chemically, gingerol is a relative of capsaicin and piperine. Capsaicin is soluble in alcohol, ether and benzene but slightly in petroleum. Pure capsaicin is a volatile, hydrophobic, colourless, odourless and crystalline to waxy compound. However piperine is highly soluble in alcohol and ether. It is believed that with these compositions as in Figure 4, during frying the ginger with UCO will exaggerate the chemical reaction therein.
2.2.3 Second step catalyzed process – Transesterification

The chemical reaction that converts a vegetable oil or animal fat to biodiesel is called "transesterification". In this transesterification reaction, an ester and an alcohol (i.e. methanol) react to form a different ester. The three fatty acid chains (R_COO”) connected to the glycerol backbone are broken at their ester bond and react with the alcohol to form alkyl esters and a glycerol molecule. Figure 5 shows transesterification reaction.
2.3 Part 3: Analysis

2.3.1 Analysis of UCO B100 biodiesel

The samples were analyzed accordingly through respected formula below:

**FFA %**

The FFA % is obtained through calculation from titration process.

\[
\frac{\text{Titrati}on \ \text{Value}}{1.3} = \text{Approximate FFA \%}
\]

Titration Value = Final reading of the burette – initial reading of burette

**Amount of catalyst**

Amount of catalyst = \( \frac{\text{NaOH constant}}{\text{NaOH Purity}} \) + Titration Value \( \times \) Volume of UCO to be process

**Conversion Analysis**

Conversion Efficiency = \( \frac{\text{Volume of biodiesel produced, g}}{\text{Volume of oil use, g}} \times 100 \% \)

**Density Analysis**

\[
\text{Density, g/ml} = \frac{\text{Mass of sample, g}}{\text{Volume of sample, ml}}
\]
2.3.2 Engine Test

Engine testing was carried out on engine bed and was done in Petrochemical Engineering Department at Politeknik Kuching Sarawak. The engine test was carried out on Megatech AFE. This engine is a SI Engine with a low compression ratio of 3:1. As illustrated in Figure 6 below, the engine comprises 2 main sections, that is the engine block section and the dynamometer section. To combust B100 inside the SI engine must be carried out carefully. Theoretically it is impossible to combust the biodiesel inside a SI engine with a low compression ratio. Two fuel tanks were provided on this engine with two intakes of fuel. Methanol being used to initiate the combustion. Combustion happens when methanol was fed on lean condition until the temperature inside the engine increased to 500°C-600°C. Adjustment on Fuel-Air Ratio (FAR) makes combustion possible between certain Limits of Flammability until it reach the Stoichiometric Ratio reaction. On the other tank B100 was fed by opening the needle valve slowly, at the same time methanol are gradually reduced by turning off the intake needle valve. Adjustment of these two valves must be carried out with precise and simultaneous adjustment.

Figure 6: Megatech AFE
3.0 RESULTS AND DISCUSSION

3.1 Plant efficiency

The yielding quantity of 15 liters plus the reactant result in generating 13 liters of biodiesel which is equivalent to 90% production efficiency. 10% glycerol produce can be used for other purpose. Duration to produce biodiesel was clocked for 30 minutes production. Four samples were tested to obtain the average Titration value of 3.0. Thus it gives the approximate percentage of FFA is 2.3%. An amount of 15 liters of UCO being tested with 132g of NaOH (95% purity). First stage reaction by frying 500g of sliced ginger. Finally the plant managed to generates 13 liters of pure B100 biodiesel.

3.2 Effects of Gingerize process on Biodiesel production

The density of the product is 0.815 g/m$^3$ that is not come to a reasonable agreement with ASTM 6751. This is might due to the interaction with gingerol composition during the frying of fresh ginger. Table 1 shows the differences of UCO B100 density which is below the ASTM 6751 standards. Biodiesel that meets international fuel standards ASTM 6751 has been accepted as an alternative for fossil diesel due to its property compatibility and comparable performance to diesel engine and most importantly because it is an environmental friendly source of energy [7]. Further investigation on the gingerol composition activity during the gingerizing reaction should be emphasized due to the ability of its chemical reaction that reduce the biodiesel density.

<table>
<thead>
<tr>
<th>Property</th>
<th>Biodiesel Standard ASTM 6751</th>
<th>UCO methyl ester (Biodiesel)</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/m$^3$)</td>
<td>0.87 – 0.89</td>
<td><strong>0.815</strong></td>
<td>0.855</td>
</tr>
</tbody>
</table>
3.3 Engine performance

The product burns very well inside the AFE as shown in Figure 7. The engine was a see-through or transparent high tempered glass cylinder wall, and the flashes of flames can be seen clearly. The yellowish flames indicate that the rich mixture of fuel combusted inside the engine. However smoke emission reduces when the RPM of the engine is higher, this indicates the complete combustion of biodiesel took place inside the engine during high RPM.

![Yellowish flame of burnt B100 inside AFE](image)

Figure 7: Yellowish flame of burnt B100 inside AFE

The results of the engine performance were plotted as shown in Figure 8. As the engine is a 3:1 low compression ratio, considered to be small to compress hot air, by exaggerating the B100 to burnt, methanol was initially fed inside the chamber for pre-combustion. Methanol was left to burnt on lean condition for 3 minutes before gradually reduces the methanol intake. Meanwhile, the B100 fuel being fed in slowly and simultaneously closing methanol needle valve as well. It was expected that the temperature inside the chamber increased to 500°C-600°C, and can easily burnt B100 without assisted by hot air compression. Figure 8 indicates that the when the loads increase, the torque will decrease. It shows that the stability of Stoichiometric Ratio ends at 1200 RPM of the engine. The engine works very well at 1400 RPM. The interceptions of curves line for torque and loads determine the engines runs smoothly with less vibration and exhaust emissions. In this engine test only torque, loads and RPM was recorded. No gas emission test was conducted.
As per said theoretically, it is impossible to burn biodiesel or fossil diesel fuel inside a SI engine, as well it is a low compression. Perhaps with the result of this preliminary study will be a new phenomenon in combustion research in the future.

![Torque and rpm vs load](image)

**Figure 8:** The engine performance graph for Gingerize B100

### 4.0 CONCLUSIONS

1. Fresh slices ginger are believe can react with NOaH and methanol quite well. For future research, dried and blended ginger to be considered as the amount of zingerone are said to be more dense compared to the fresh one.

2. The density of the product is 0.815 g/m³ and FFA in the UCO is 2.3%, considered to be lighter than normal diesel and ASTM 6751 standard.

3. The gingerize process provides a simple and economic method to exaggerate the reaction was it can be produced locally.

**REFERENCES**


Monge, P; Scheline, R; Solheim, E (1976). "The metabolism of zingerone, a pungent principle of ginger". *Xenobiotica; the fate of foreign compounds in biological systems* 6 (7): 411–23.

