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BIODIESEL PRODUCTION FROM GREASE TRAP WASTE AND ITS PURIFICATION USING ACTIVATED BIOCHAR DERIVED FROM WOODCHIPS BIOMASS

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NURHANI FATIHAH BINTI JARIAH

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Depletion of non-renewable fossil fuels and growing environmental awareness have attracted extensive research worldwide towards biodiesel. It is clean, safe, biodegradable, and renewable. Presently, grease trap waste (GTW) appears to be an alternative feedstock for biodiesel production, while woodchips biomass is more suitable as bioadsorbent for biodiesel purification. In this study, production of biodiesel from grease trap waste was achieved by using both esterification and transesterification processes. After esterification, the free fatty acid (FFA) content in the esterified oil is reduced to 0.61% with 95% of FFA conversion. Under the best conditions of 6:1 methanol to oil molar ratio, 1.5 wt% catalyst loading, at 40°C for 2 h, 87% of fatty acid methyl ester (FAME) yield was achieved. The purification of crude biodiesel using activated biochar from woodchips biomass was performed using different adsorbent loadings (0.025 to 0.125 g/L) under continuous stirring condition at 150 rpm for different residence time (20 to 100 mins). The activated biochar was characterised by Brunauer-Emmett-Teller (BET) surface area, scanning electron microscopy with energy dispersive X-ray (SEM-EDX), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). Approximately, 98.2% of free fatty acid and 67.9% of soap content were successfully removed after purification at 0.05 g/L of activated biochar loading for 1 h. The fuel properties of the purified biodiesel (density, kinematic viscosity, flash point, cloud point, and pour point) were found to be in good agreement with the EN14214 and ASTM D6751 standards outlined for FAME fuel engines. Therefore, this study has shown the potential and the effectiveness of using waste material

both as feedstock and purifier in biodiesel production; making the process more sustainable for the environment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGHASILAN BIODIESEL DARIPADA SISA PERANGKAP GRIS DAN PENULENANNYA MENGGUNAKAN BIOARANG TERAKTIF DARIPADA BIOJISIM SERPAI KAYU

Oleh

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Pengurangan bahan api fosil yang tidak boleh diperbaharui dan kesedaran alam sekitar yang semakin meningkat telah menarik banyak penyelidikan secara meluas di seluruh dunia terhadap biodiesel. Biodiesel mempunyai banyak manfaat seperti bersih, selamat, biodegradasi, dan boleh diperbaharui. Kini, sisa perangkap gris (GTW) muncul sebagai satu bahan mentah alternatif bagi penghasilan biodiesel dan biojisim serpai kayu adalah lebih sesuai dijadikan agen biopenjerap untuk proses penulenan biodiesel. Dalam kajian ini, penghasilan biodiesel daripada sisa perangkap gris telah dihasilkan melalui kaedah pengesteran dan pentransesteran. Setelah pengesteran dilakukan, kandungan asid lemak bebas (FFA) di dalam minyak terester telah berkurang sebanyak 0.61% dengan 95% penukaran asid lemak bebas. Dalam keadaan yang terbaik, ia mendapati 6:1 nisbah molar metanol kepada minyak, 1.5% berat pemangkin pada 40°C selama 2 jam, telah menghasilkan 87% metil ester asid lemak (FAME). Proses penulenan biodiesel mentah dengan menggunakan bioarang teraktif daripada serpai kayu telah dijalankan menggunakan muatan penjerap yang berbeza (0.025 hingga 0.125 g/L) dalam keadaan pengacauan berterusan pada kelajuan 150 rpm selama 1 jam bagi tempoh masa yang berbeza (20 hingga 100 minit). Bioarang teraktif telah dicirikan dengan menggunakan pengukuran luas permukaan Brunauer-Emmett-Teller (BET), mikroskop elektron imbasan dengan sebaran tenaga sinar-X (SEM-EDX), pembelauan sinar-X (XRD) dan spektroskopi transformasian Fourier inframerah (FTIR). Kira-kira, 98.2% asid lemak bebas dan 67.9% kandungan sabun telah berjaya disingkirkan setelah menjalankan proses penulenan dengan 0.05 g/L muatan bioarang teraktif selama 1 jam. Ciri-ciri biodiesel tulen (ketumpatan, kelikatan kinematik, titik nyala, takat awan, dan takat curah) didapati selari

dengan standard EN14214 dan ASTM D6751 yang telah digariskan untuk enjin bahan bakar FAME. Oleh itu, kajian ini menunjukkan keupayaan dan keberkesanan penggunaan bahan buangan sama ada sebagai bahan mentah atau sebagai agen penulen dalam penghasilan biodiesel; dan seterusnya menjadikan proses ini lebih lestari kepada alam sekitar.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

FAME	Fatty acid methyl ester
GTW	Grease trap waste
EN	European standard
ASTM	American Society for Testing and Materials
JPSPN	Jabatan Pengurusan Sisa Pepejal Negara
MSW	Municipal solid waste
DBKL	Kuala Lumpur City Hall
MBPJ	Majlis Bandaraya Petaling Jaya
GGSWAC	gasified *Glyricidia sepium* woodchip
KOH	Potassium hydroxide
$ZnCl_2$	Zinc chloride
H_2	Hydrogen gas
H_3PO_4	Phosphoric acid
GHG	Greenhouse gases
CDM	Clean Development Mechanism
EASAC	European Academies Science Advisory Council
FOG	Fat, oil, and grease
FFA	Free fatty acid
H_2SO_4	Sulphuric acid
HCl	Hydrochloric acid
HF	Hydrofluoric acid
NaOH	Sodium hydroxide
CH_3ONa	Sodium methoxide
SCO	Spent cooking oil

SFFO	Spent fish frying oil
BET	Brunauer-Emmett-Teller
SEM-EDX	Scanning electron microscopy with energy dispersive X-ray
kV	Kilovolt
XRD	X-ray diffraction
FTIR	Fourier transform infrared spectroscopy
Cu	Copper
ATR	Attenuated total reflectance

CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays, there is an increasing trend in global energy demand due to rapid industrialisation and population growth (Sadaf *et al*., 2018). However, main energy resources like natural gas and hydrocarbon-based fuel like diesel and coal are steadily depleting because they are non-renewable in nature (Arshad *et al*., 2018). Furthermore, substantial reliance on diesel as a primary source of fuel, particularly in transportation and power generation, has driven hydrocarbon-based fuel costs to rise progressively. In addition, the use of non-renewable energy also has a devastating impact to the environment and its biodiversity. In order to rectify this issue, tremendous efforts are currently being made to find the best alternative fuels that not only can reduce hydrocarbon-based energy consumption, but also curb environmental deterioration. This can be done by the production of biofuels from renewable sources (Hiwot & Maryo, 2015; Kumar *et al*., 2020).

Among the variety of biofuels, biodiesel has attracted extensive research worldwide (Ardi *et al*., 2015). Biodiesel, or also known as fatty acid methyl ester (FAME), is a diesel fuel substitute derived from the transesterification reaction of triglycerides with an alcohol in the presence of a catalyst. Besides its renewability, biodiesel is a preferred energy source compared to petroleum-based fuel because it is sustainable, biodegradable, and it is also a clean-burning fuel (Ahmad Farid *et al*., 2017; Hazmi *et al*., 2020).

Despite the obvious advantages of using biodiesel as an alternative fuel source, its production cost is the major set-back in the commercialisation of biodiesel. Hence, the use of waste materials for the generation of biodiesel may be helpful to cut back the feedstock value, making the production more economical. For example, grease trap waste (GTW), typically found in food and beverage businesses, can be potentially used as feedstock for biodiesel production since it possesses a high lipid content (Tran *et al*., 2018). GTW is abundant and may be a more cost-effective feedstock. This is because initially, GTW has a negative added value, whereby premise owners are required to pay for its disposal. Therefore, acquiring GTW will incur little to no charge (Montefrio *et al*., 2010). In addition, utilising this waste may also minimise land and water pollution since the waste oil is converted into a valuable product (Sadaf *et al*., 2018). This added benefit is important because these wastes are simply disposed into the environment despite many developed and developing countries setting up policies for a more efficient and environmentally-friendly disposal of waste oil into the sewer system (Patil *et al*., 2012).

Besides the cost of the feedstock, another economical challenge for the production of biodiesel is its purification. This is because residues such as remaining soap and free fatty acids will result in low-quality biodiesel. According to White *et al*. (2010) the presence of soap in biodiesel can contribute to filter plugging and engine deposits when used as a fuel, thus, affecting the engine performance of vehicles (Demirbas, 2009). However, biodiesel purification using conventional method which is the washing method (washing by water), produced large volumes of wastewater, making it counter-productive in establishing biodiesel as a green energy source (Fadhil & Abdulahad, 2014). Therefore, an alternative method such as dry washing techniques using activated biochar was established (Ostojčić *et al*., 2020). They are also found to be very efficient in removing organic and inorganic impurities that satisfy the standards specifications stated in European Standard (EN), EN14214 and the American Society for Testing and Materials (ASTM), ASTM D6751 (Bateni *et al*., 2017).

As such, naturally derived adsorbents such as woodchips biomass has been increasingly used in downstream processes of biodiesel production. This is due to their special characteristic in adsorption capacities (contributed by its high porosity and large surface area) as well as generating similar quality fuel products when compared to conventional purifiers (Avinash & Murugesan, 2017; Ortiz-Monsalve *et al*., 2020). In addition, purification using this bio-adsorbent can be conducted at room temperature, thus, avoiding heating of biodiesel to prevent the generation of by-product by the thermal degradation of biodiesel. Moreover, woodchip biomass' popularity can also be attributed to being widely available, renewable, and virtually free. This can ensure the sustainability and the eco-friendliness of biofuel production.

1.2 Problem statement

There has been a growing worldwide demand for renewable sources to substitute fossil fuels. In this context, biodiesel is considered a viable alternative fuel. However, the major problems regarding the use of biodiesel as alternative fuel are its production cost and other economic issues such as lower dependency and development of less-favored regions (Mizik & Gyarmati, 2021). In fact, the market price for biodiesel is still higher than petroleum-based diesel even though it has been subsidised by the government. This is because, it has been accounted that 95% of the global biodiesel production depends on edible oil as a feedstock and thus, drives the biodiesel costs to rise progressively. Apart from that, utilisation of the edible oil as a feedstock also led to food versus fuel issues where the food industry and energy producers are competing toward the same source of oils. Besides that, in biodiesel production itself, about 70 to 80% of the total biodiesel production cost is accounted by the feedstock used, thus, will eventually become unattractive for industrial scale production (Ideris *et al*., 2021). Therefore, it is necessary to find cheap raw materials to be used as a feedstock for production of biodiesel. In this study, grease trap waste (GTW) was selected as a feedstock in biodiesel production.

There is limited to zero usage of GTW conventionally, therefore, it is being sent to wastewater treatment facility as it poses environmental threat, along with its treatment costs. Furthermore, due to lack of proper disposal and poor maintenance of grease traps, GTW will simply flow into the sewer system, causing the build-up of fatbergs, and subsequent pipe blockages (Tatiparthi *et a*l., 2021). This is due to some of the eatery operators simply violating the law on maintaining the grease traps. Because of the aforementioned problems, it is more beneficial to utilise GTW as a low-cost feedstock for the biodiesel production instead.

Besides that, biodiesel purification method is important to enhance the quality of the product in meeting the international biodiesel specification (EN14214 and ASTM D6751). After transesterification, the presence of unwanted residuals in biodiesel such as FFA, soaps, moisture, remaining alcohols, and unreacted glycerides will lower the fuel's quality. Traditionally, water washing method was used to purify the crude biodiesel. However, this method produces a large amount of effluents that needs to be treated before discharging to environment, thus, incurring extra costs in the biodiesel production. Therefore, dry washing method using activated biochar was found to be a promising approach with no wastewater produced and less product loss. Moreover, the activated biochar has excellent properties that helps in removing the impurities, making the purification process more effective. Fadhil and Dheyab (2015) found that the utilisation of activated biochar in the biodiesel purification resulted in a better FAME yield and quality compared to water washing.

Furthermore, according to JPSPN (2012), about 6% of the total solid waste generated comprises of landscaping waste in Malaysia. These wastes are being disposed in the landfills with no use, therefore in response to the "Waste-to-Wealth" project, woodchips biomass can be utilised as a good precursor for alternative activated biochar because it is freely accessible and abundant (Cao *et al*., 2018). Therefore, by using waste material as feedstock and also in the purification system, not only the production of biodiesel becomes more economically sustainable, but also helps in reducing environmental problems as well.

1.3 Research objectives

The main objectives of this study are

1) To determine the best conditions for biodiesel production from grease trap waste.

2) To purify the biodiesel using activated biochar derived from woodchips biomass to meet EN14214 and ASTM D6751 standard.

1.4 Scope of study

In this study, grease tap waste (GTW) was chosen as raw feedstock for the biodiesel production. This GTW solely collected at R&R Ayer Keroh, Melaka and the result related to GTW will be applied from this area only and cannot be generalized to other parts of Malaysia. In esterification, sulphuric acid act as acid catalyst is believed to reduce free fatty acid content to less than 2% before proceed to transesterification process. Then, transesterification of GTW with methanol and potassium hydroxide as base catalyst to biodiesel was conducted under reflux condition. Hence, finding the best conditions for the highest biodiesel yield were carried out by determining the effect of methanol to oil molar ratio, catalyst loadings, reaction temperature and reaction time. Besides, biodiesel purification using activated biochar derived from woodchips biomass was performed and the fuel properties were tested at Intertek, Port Klang. Both of the study on the production and purification of biodiesel will also be limited to laboratory scale.

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