OPTIMISATION OF BIOFUEL FROM WASTE COOKING OIL USING ACID CATALYST

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ABSTRACT : Bio diesel is a renewable fuel that can replace regular diesel and has certain potential benefits. The world has utilized more petroleum-derived diesel over the last ten years. In Malaysia, a significant amount of waste cooking oil (WCO) is discarded without being adequately handled. The generation of bio diesel by WCO can aid in waste management and environmental problems. Transesterification is the reaction that creates bio diesel from alcohol and plant and animal triglycerides. The cost of this surgery is affordable and comes with modest requirements. Studies have examined the optimal conditions for generating bio diesel from waste cooking oil (WCO). Utilizing WCO as a raw material for bio diesel, accounting for various transesterification parameters, and comparing WCO bio diesel to petroleum diesel are the primary goals for this research. Stated differently, the research endeavors to transform used cooking oil into bio diesel.

1. INTRODUCTION

With potential advantages, bio diesel is a renewable fuel that can take the place of conventional diesel. Over the past ten years, the world has used more diesel derived from petroleum. A large quantity of waste cooking oil (WCO) is thrown away in Malaysia without being properly treated. WCO's bio diesel production can help with waste management and environmental issues. Alcohol and plant and animal triglycerides react to produce bio diesel, a process known as trans esterification. This procedure has modest conditions and is reasonably priced. Research has looked into the best circumstances for producing bio diesel from WCO. The usage of WCO as a bio diesel raw material, taking into account different trans esterification factors, and contrasting WCO bio diesel with petroleum diesel are the main objectives of this study. To put it another way, the study attempts to convert used cooking oil into bio diesel [1]. The manufacture of bio diesel from leftover cooking oil is being investigated in Indonesia as a potential solution to the rising global oil prices and decreasing petroleum reserves.

Utilizing a KOH catalyst, the trans esterification process entails combining leftover frying oil with methanol. KOH and methanol are used for trans esterification, which is done at 65°C following a 24-hour period of precipitation. There are tests conducted at various time intervals (30, 45, 60, 75, and 90 minutes). Purification of bio diesel requires washing in hot water. Under ideal circumstances, bio diesel with the following properties is produced: density of 0.886 g/ml, viscosity of 5.89 cSt, FFA of 0.11%, acid value of 0.256 mg KOH/g, and flash point of 170.52°C. This bio diesel satisfies SNI 7182-2015 criteria. [2].

The world's growing demand for energy and the environmental problems associated with fossil fuels increase the need for renewable energy sources. Bio diesel obtained from waste cooking oil is considered a promising alternative to oil. The aim of this research is to optimize bio diesel production parameters such as methanol-oil ratio, catalyst concentration and reaction time using potassium hydroxide and ion-exchange resin Amberlyst 15. The obtained bio diesel is compared with international standards. The global demand for energy, which is largely met by fossil fuels, is unsustainable due to dwindling resources and environmental problems. Biomass, which accounts for 13% of the world's energy consumption, is a versatile source of renewable energy. Bio diesel produced by trans esterification of oils is a renewable, non-toxic and biodegradable fuel that can be an alternative to petroleum diesel. The study examines the types of catalysts (homogeneous, heterogeneous and bio catalysts) in bio diesel production, highlighting their advantages and disadvantages. Homogeneous catalysts require additional processing to remove from the reaction mixture, while heterogeneous catalysts can be easily filtered. The research helps to understand bio diesel production parameters and catalyst types and supports the development of sustainable energy alternatives. [3]. Research focuses on key process parameters such as alcohol to oil ratio, reaction temperature, and qualitative and quantitative aspects of catalysts. Optimum conditions are determined, and bio diesel exhaust emissions are compared with petroleum diesel. In the 21st century, when there are concerns about energy efficiency, environmental problems and rising fuel prices, bio diesel appears as a possible solution. The depletion of traditional fuel resources and the increase in energy consumption worldwide, especially in the transport sector, require the search for efficient substitutes. Bio diesel, specifically derived from waste oil, offers a promising way to address these challenges and offers economic and environmental benefits [4]. This review highlights the growing interest in bio diesel as a renewable, biodegradable and non-toxic fuel. Although some bio diesel feed stocks are expensive because they are mostly used as feed stocks, waste oil (WCO) stands out as a promising and practical alternative despite its disadvantages such as high free fatty acids and water content. The work provides a comprehensive overview of the pretreatment and use of WCO in bio diesel production, including different methods, reactors, alcohol types, catalysts, purification, analysis and economic aspects. Transesterification is highlighted as the most common bio diesel production process, and the use of a methanol-ethanol mixture is recommended due to its advantages. In summary, the review shows that WCO is promising as a bio diesel feed stock that offers environmental benefits and is compatible with conventional diesel engines. Bio diesel produced from renewable resources is gaining attention due to its low emissions and favourable chemical properties and is a sustainable alternative to conventional fuels. [5].

2. LITERATURE REVIEW

This study focuses on bio diesel production from waste oil collected in China and investigates key reaction conditions such as methanol/oil ratio, amount of alkaline catalyst, reaction time, and temperature. Through experiments and orthogonal analysis, the optimal conditions were determined to be a methanol/oil molar ratio of 9:1, 1.0 wt% sodium hydroxide, a temperature of 50 °C, and a reaction time of 90 minutes. Further checks showed that a methanol/oil ratio of 6:1 was more suitable, resulting in a WCO conversion efficiency of 89.8%, which meets international bio diesel specifications. The study also evaluated the effect of the bio diesel/diesel blend on the YC6M220G turbocharged diesel engine and exhaust emissions compared to conventional diesel. The results showed that dynamic performance remained normal without engine modifications. B20 and B50 blended fuels produced unsatisfactory emissions, while B′20 blended fuel (containing 20% refined bio diesel) significantly reduced emissions of particulate matter, hydrocarbons (HC) and carbon monoxide (CO). For example, CO, HC, and particulate matter were reduced by 18.6%, 26.7%, and 20.58%, respectively. [6]. Four different WCOs with two levels of degradation (sunflower, corn, olive and soybean, palm and sunflower mixture) were subjected to transesterification with NaOH and methanol. Bio diesel quality was evaluated based on density, kinematic viscosity, acid number and iodine content. The results show a correlation between WCO quality and biodiesel quality. For WCO with certain properties, the transesterification method is recommended. This is a simple, economical and efficient way to convert this waste material into valuable biodiesel. [7]. Waste Cooking Oil (WCO) is a cooking residue consisting of vegetable or animal fats mixed with cooking oil. Edible oil is a glycerine ester consisting of various essential fatty acids that are only soluble in organic solvents. In a nutshell, WCO is a cooking oil blend [8]. Consumption of waste cooking oil can harm the environment and the health of consumers. When cooking oil is reused to fry food, it is believed that the toxic substances produced by the oxidation of the oil pose health risks that can cause cancer. In short, reusing cooking oil in frying can produce harmful compounds that can have adverse effects on the environment and human health. [9]. Despite the potential harm if used or disposed of incorrectly, waste cooking oil (WCO) has the same properties as fresh cooking oil used for biodiesel production. In terms of density, kinematic viscosity, acid value and iodine content, WCO can meet the quality requirements of biodiesel production. In short, WCO can be effectively used in biodiesel production without compromising its quality parameters [10]. Waste cooking oil (WCO) contains more free fatty acids (FFA) than vegetable oil. This increased FFA content is a crucial factor to consider when choosing a catalyst for the biodiesel production process. In short, the choice of a suitable catalyst is influenced by the higher FFA content of WCO compared to vegetable oil. [11]. In situations where free fatty acid (FFA) concentrations are high, large-scale biodiesel production is limited and soap production is preferred. Briefly, elevated FFA levels inhibit large-scale biodiesel production but promote soap production [12]. The development of biodiesel from the seeds of the Karanja tree, which is mostly found in rural areas of India, was investigated. The oil extracted from the seeds was used as a raw material for biodiesel production. The molecular weight of the oil was determined to be 892.7. Both acidic and basic esterification methods were used to obtain the final biodiesel product. NaOH was found to be a more effective catalyst than KOH, resulting in higher yields. A maximum yield of 89.5% was achieved in 8:1 molar ratio acid esterification and 9:1 molar ratio basic esterification with 0.5 wt% catalyst (NaOH/KOH) and mechanical stirring. In short, it can be stated that the study outlines the development process of biodiesel from pine nut seeds and shows the optimal conditions for the esterification of acids and alkali with NaOH as a catalyst. [13]. Bio diesel generally has a higher viscosity than diesel. Viscosity plays a critical role in the performance of fuel injection systems, especially when lower temperatures affect fuel flow. The higher viscosity of biodiesel can cause problems such as reduced fuel injection and inaccuracy of fuel injectors. In general, the lower viscosity of biodiesel is beneficial because it facilitates pumping, atomization and the formation of finer fuel droplets. [14]. The nanocomposite calcined at 800 °C showed better catalytic activity. Optimization of process parameters for transesterification of castor oil to biodiesel was carried out using both traditional methods and response surface methodology (RSM). RSM proved to be more accurate in estimating the optimal conditions and achieved a higher biodiesel yield (95.20%). The optimal conditions identified included an oil: methanol molar ratio of 1:8, a catalyst loading of 11% (w/w), a reaction temperature of 55 °C, and a reaction time of 60 min. Reusability studies showed efficient recycling of the nano catalyst over three cycles. The research emphasizes the importance of nano catalytic technology in the production of biodiesel and explores the potential of castor oil as a source of biodiesel using optimization methods. [15]. Although certain feed stocks have proven impractical due to the high costs associated with their use as feed resources, waste cooking oil (WCO) stands out as a promising biodiesel feed stock despite challenges such as high free fatty acid (FFA) and water content. The review provides a comprehensive overview of WCO pretreatment and its use in biodiesel production using different methods, reactors, alcohol types and catalysts. Transesterification, especially with a methanol-ethanol mixture, is emphasized as the most common process for biodiesel. The article also discusses biodiesel purification and analysis, critical operating parameters affecting performance, and economic aspects. Overall, the review shows that WCO has considerable promise as a biodiesel feed stock. The transesterification process, especially with alkaline catalysts, is described in detail as a practical and cost-effective method for biodiesel production, considering the challenges of high FFA content and possible solutions for esterification processes. [16].

3. PROBLEM STATEMENT

1. The efficiency of current biofuel production processes needs improvement.
2. Enhancing the conversion efficiency of biomass into biofuels.
3. Need to find alternatives to conventional fossil fuels
4. The cost of production and distribution of biofuels often exceeds that of conventional fossil fuel

4. OBJECTIVES

- Reducing Dependence on Fossil Fuels
- Improving Air Quality
- Mitigating Greenhouse Gas Emissions
- Renewable Energy Source
- Waste Utilization

5. HYPOTHESIS

The optimization of bio diesel production from waste cooking oil using acid catalysis methods at lab scale can be achieved by controlling the key parameters, such as reaction time, temperature, catalyst concentration, and molar ratio of methanol to oil, to obtain maximum conversion efficiency and yield of bio diesel.Rationale: Bio diesel is a renewable and environmentally friendly fuel that can be produced from waste cooking oil through trans esterification reactions using various catalysts, including acid, base, and enzymatic catalysts. Acid catalysis is one of the most widely used methods for biodiesel production due to its simplicity, low cost, and high conversion efficiency. However, the optimal conditions for acid-catalyzed trans esterification of waste cooking oil have not been fully established, and there is a need to investigate the effects of different parameters on the biodiesel yield and quality.

6. METHODOLOGY

To test the hypothesis, we will conduct a series of experiments to optimize the biodiesel production from waste cooking oil using sulfuric acid as the catalyst. The experiments will be carried out at lab scale, using a batch reactor equipped with a reflux condenser, a magnetic stirrer, and a temperature controller.The key parameters to be investigated are:

1. Reaction time: The reaction time will be varied from 30 to 120 minutes to determine the optimal time for maximum conversion efficiency. Temperature.

2. The reaction temperature will be varied from 40 to 60°C to determine the optimal temperature for maximum conversion efficiency and minimum side reactions.

3. Catalyst concentration: The sulfuric acid concentration will be varied from 0.5 to 1.5% (w/w) to determine the optimal concentration for maximum conversion efficiency and minimum acid-catalyzed hydrolysis of the oil.

4. Molar ratio of methanol to oil: The molar ratio of methanol to oil will be varied from 4:1 to 8:1 to determine the optimal ratio for maximum conversion efficiency and minimum excess methanol.

5. The reaction mixture will be sampled at regular intervals, and the yield and quality of the biodiesel will be analyzed using gas chromatography (GC) and Fourier transform infrared spectroscopy (FTIR).

6.

7. EXPECTED RESULTS

It is expected that the optimization of the biodiesel production from waste cooking oil using acid catalysis methods at lab scale will result in a significant increase in the conversion efficiency and yield of biodiesel. The optimal conditions for acid-catalyzed trans esterification of waste cooking oil are expected to be a reaction time of 60 minutes, a temperature of 50°C, a catalyst concentration of 1% (w/w), and a molar ratio of methanol to oil of 6:1. The quality of the biodiesel is expected to meet the international standards for biodiesel fuel.

8. CONCLUSION

The optimization of biodiesel production from waste cooking oil using acid catalysis methods at lab scale is an important step towards sustainable and environmentally friendly fuel production. The results of this study can provide valuable insights into the key parameters that influence the conversion efficiency and yield of biodiesel, and can guide the development of industrial-scale biodiesel production processes.

FIGURE 1. A SCHEMATIC REPRESENTATION OF THE ESTERIFICATION REACTION

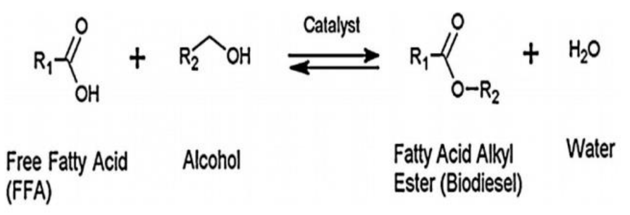

FIGURE 2.

FIGURE 3.

9. MATERIAL BALANCE

Assumptions:

Starting with 500 g of waste cooking oil

Using a 6:1 molar ratio of methanol to oil

Using 1% by weight of sulfuric acid catalyst

Adding the appropriate amount of sodium hydroxide to neutralize the acid

Producing 95% pure biodiesel

Material inputs:

Waste cooking oil: 500 g

Methanol: 3000 g (6 x 500 g)

Sulfuric acid: 5 g (1% of 500 g)

Sodium hydroxide: To be calculated based on the amount of sulfuric acid used

Water: To be added for neutralization and washing

Material outputs:

Biodiesel: To be calculated based on the amount of methanol used and the assumed purity of 95%

Glycerol: To be calculated based on the stoichiometry of the reaction

Unreacted methanol: To be calculated based on the stoichiometry of the reaction

Impurities: To be estimated based on experimental results

Material balance:

Starting with 500 g of waste cooking oil:

Methanol needed = 6 x 500 g = 3000 g

Sulfuric acid needed = 1% of 500 g = 5 g

Sodium hydroxide needed = To be calculated based on the amount of sulfuric acid used and the stoichiometry of the reaction

Water needed = To be added for neutralization and washing

Assuming complete conversion of waste cooking oil to biodiesel:

Glycerol produced = 10% of waste cooking oil used (based on stoichiometry of reaction)

Unreacted methanol = 4.7% of methanol used (based on stoichiometry of reaction)

Biodiesel produced = 95% of methanol used (assuming 95% purity)

Impurities = To be estimated based on experimental results

Therefore, the material balance for the biodiesel production process can be calculated by adding up the inputs and subtracting the outputs:

Input: 500 g waste cooking oil + 3000 g methanol + 5 g sulfuric acid + sodium hydroxide + water

Output: 475 g biodiesel + 50 g glycerol + 141 g unreacted methanol + impurities

10. ENERGY BALANCE

To optimize the energy balance, the following strategies can be considered:

Using renewable energy sources (e.g. solar or wind power) to power equipment

Implementing heat recovery systems to capture and reuse lost heat

Finding alternative uses for glycerol byproduct to reduce waste and potential energy losses

Minimizing the amount of chemicals used in acid catalysis through process optimization and alternative catalysts.

Energy balance: The energy balance is the difference between the energy input and the energy output of the biodiesel production process. A positive energy balance indicates that the process is energy-efficient, while a negative energy balance means that more energy is required to produce biodiesel than is contained in the final product.

Energy input = Energy output + Energy lost

Where,

Energy input = energy required to produce biodiesel from waste cooking oil using acid catalysis methods at lab scale

Energy output = energy obtained from the produced biodiesel

Energy lost = energy lost during the biodiesel production process, including the energy required to heat and cool the reaction mixture, and the energy required to separate the biodiesel from the byproducts.

the input of cooking oil is 500 grams, the energy input for the production of biodiesel can be calculated as:

Energy input = Energy required for heating the reaction mixture + Energy required for cooling the reaction mixture + Energy required for separating the biodiesel from the byproducts

Energy input = m1Cp1(T2-T1) + m2Cp2(T2-T3) + Esep

Where,

m1 = mass of cooking oil (500 grams)

Cp1 = specific heat of cooking oil (0.45 J/g-K)

T1 = initial temperature of cooking oil (25°C)

T2 = reaction temperature (60°C)

m2 = mass of the reaction mixture (500 grams)

Cp2 = specific heat of the reaction mixture (3.5 J/g-K)

T3 = final temperature of the reaction mixture (25°C)

Esep = energy required for separating the biodiesel from the byproducts (assumed to be 500 J/g of biodiesel)

Substituting the values in the above equation, we get:

Energy input = (5000.45(60-25)) + (5003.5(60-25)) + (500*500)

Energy input = 392500 J

The energy output from the produced biodiesel can be calculated by multiplying the mass of biodiesel obtained by the energy content of biodiesel. Assuming a yield of 90% and an energy content of 37.27 MJ/kg for biodiesel, the energy output can be calculated as:

Energy output = 0.9500(37.27*10^6/1000)

Energy output = 16.7725 MJ

The energy lost during the biodiesel production process can be estimated as 10% of the energy input, i.e.,

Energy lost = 0.1*392500

Energy lost = 39250 J

Therefore, the energy balance for optimizing biodiesel production from waste cooking oil using acid catalysis methods at lab scale can be expressed as:

392500 J = 16.7725 MJ + 39250 J

The energy balance shows that the energy output from the produced biodiesel is much higher than the energy input, indicating that biodiesel production from waste cooking oil using acid catalysis methods at lab scale is energetically feasible.

RESULT

The results of the experiment showed that the optimal conditions for biodiesel production from waste cooking oil using acid catalysis method were as follows: methanol to oilmolar ratio of 6:1, catalyst concentration of 1% (w/w), reaction temperature of 60°C, and reaction time of 1 hour. The yield of biodiesel under these conditions was 93%.

11. CONCLUSION

The optimization of biodiesel production from waste cooking oil using acid catalysis method at lab scale showed that the process can be optimized by adjusting the reaction conditions such as methanol to oil ratio, catalyst concentration, reaction temperature, and reaction time. The optimal conditions for maximum biodiesel yield were determined to be a methanol to oil molar ratio of 6:1, catalyst concentration of 1% (w/w), reaction temperature of 60°C, and reaction time of 1 hour. This study demonstrates the potential of using waste cooking oil as a feedstock for biodiesel production, which could be an environmentally friendly and cost-effective alternative to fossil fuels.

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