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Transesterification of Waste Cooking Oil Using Natural and Chemical Materials as Catalyst

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Abstract Due to the greenhouse effect of increased fossil fuel use, resulting in an increase in the period during which fossil fuels will remain available. Because of its advantages for the environment and its production from renewable resources, biodiesel has grown more appealing. As there is a supply of used cooking oil, interest in producing biodiesel is rising. This research examines how CaO and sawdust function as heterogeneous catalysts in transesterification regarding ethanol to produce bio-diesel from the used cooking oil. The impacts of the subsequent variables on the yield of the created biodiesel were investigated. Those parameters include the catalyst concentration (0.5-3 wt%), reaction period (1-4 hr), the molar ratio of ethanol to oil (8:1– 20:1), and temperature (45 to 80 °C). This led to the discovery that CaO catalyst is more efficient compared to the sawdust catalyst, with the maximum percentage yield being 75% for the sawdust catalyst and 95% for the CaO catalyst under catalyst conditions (0.50%), ethanol oil molar ratio of 20:1, and 65 Celsius temperature for 3 hours. It was evident from the results that the biodiesel fuel produced by the catalyst developed in this study fell within the acceptable range of biodiesel fuel.

Introduction

With growing environmental concerns and global oil reserves depleted, there is a strong demand for other sources of petroleum-based fuel, such as gasoline and diesel [1].Currently, transportation is virtually totally reliant on petroleum-derived fuels globally. Petroleum is one of the limited sources of fuel that has become increasingly expensive and scarce [2] and is one of the primary sources of the emissions of the anthropogenic carbon dioxide (CO2) into the atmosphere. In addition, the presence of sulphur in diesel has severely limited its use as a result of pollution and corrosion. Scientists have had to look at alternative forms of renewable energy [3].

Biofuels are an alternative to petroleum-based transport fuels that can be useful for improving energy security while reducing greenhouse gas (GHG) emissions and urban air pollution. Biodiesel is a modern alternative diesel fuel explored as a potential alternative to the conventional diesel [4].

Biodiesel can be defined as a blend of fatty acid methyl esters (FAME) that is made of oil feedstocks like the non-edible oils, vegetable oils, waste cooking oils, animal oil/fats, and tallow that may be utilized in diesel engines with no changes [5]. Blending and direct use of microemulsions, vegetable oils, transesterification, and thermal cracking are the most common processes for producing biodiesel [6]. Transesterification is considered as the most popular process for synthesizing biodiesel among all of the approaches described above. With the existence of catalyst, transesterification represents the reaction of oil or fat with alcohol that leads to producing glycerol or esters. Due to its high costs and low production, refined edible oils such as rapeseed oil, soybean oil and palm oil are not referred to as raw materials in developed countries[7]. As a result, animal fats, non-edible plant oil, and waste cooking oil have been utilized. Transesterification might be catalyzed in a variety of ways, including with homogeneous acids, heterogeneous bases, homogeneous bases, enzymes, heterogeneous acids, carbon-based catalysts, ionic liquids, etc. [8]. The quick

reaction rates of homogeneous base catalysts account for their general acceptance. This procedure has many disadvantages since it takes a lot of energy to purify the product and separate the catalysts that are not reusable, resulting in large chemical waste and energy waste [9].

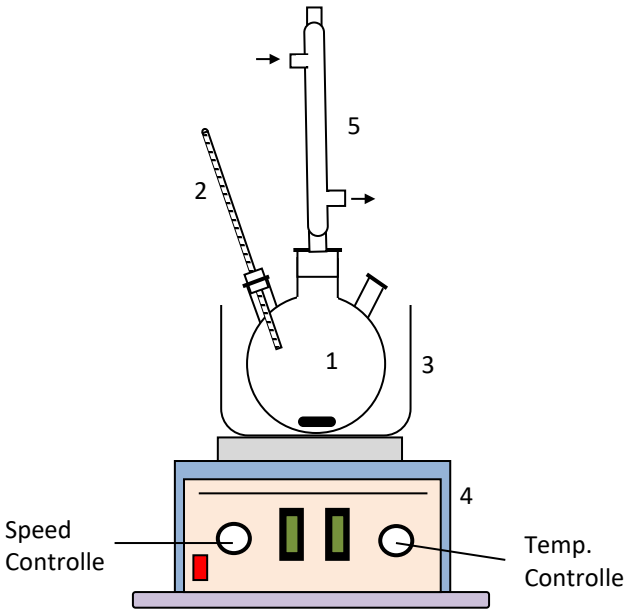
At the end of the reaction, heterogeneous catalysts can be readily isolated from the products and reused in the subsequent reaction cycle.Alkaline and alkali earth oxides [10], mixed metal oxides [11], and supported alkali metal catalysts are all examples of heterogeneous base catalysts [12].

This study intends to create biodiesel from waste cooking oil utiizing a heterogeneous catalyst made from waste (saw dust). In addition, it focuses on investigating the effects of different variables on the catalysis process, such as ethanol: oil molar ratio, reaction duration, catalyst percentage, and temperature for the purpose of establishing the best conditions for biodiesel generation.

Materials and Method

In this study, waste cooking oil (WCO) has been utilized as the base oil for transesterification, while ethanol was utilized as alcohol, which was obtained from Hayman Ltd, East Ways Park, UK. Saw dust was employed as a heterogeneous catalyst and calcium oxide was made through calcining calcium carbonate at a temperature of 900°C for 90min to be utilized as a catalyst as well. In a 3-necked glass reactor (i.e. batch reactor), the transesterification reaction has been carried out as shown in Fig. 1. A condenser was installed in the middle of the reactor's necks for condensing ethanol vapors, a thermometer in one of the necks, and a withdrawn sample in the third neck. The reaction flask has been filled with waste cooking oil and heated till reaching the desired level by the reaction temperature. Also, the heat controller was a magnetic stirrer which changed the heating power to achieve the desired reaction temperature. The catalyst and alcohol are added after reaching the required temperature. Then, agitation began at 600 rpm to ensure proper mixing of the compounds and to avoid any potential mass transfer issues.This was the starting point of reaction. Furthermore, the reaction mix has been transferred into a separating funnel and was left to settle for a period of 24 hours after it was done. According to the density difference, the biodiesel has been separated from residue's top layer and the yield was determined using Eq. (1).

$$\text{Biodiesel yield} = \frac{volume\ of\ biodiesel}{volume\ of\ raw\ oil} \quad (1)$$



(1) Neck flask, (2) thermometer, (3) water bath, (4) magnetic stirrer, (5) condenser

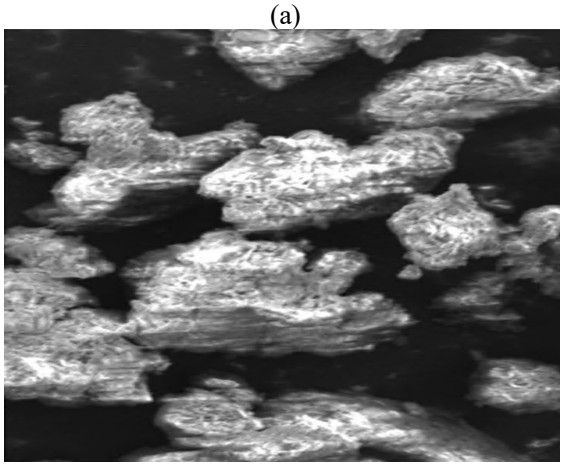
Figure 1: Diagram of equipment

Results and Discussion

Scanning electron microscopy

Using SEM, researchers could examine the catalyst's particle size and surface morphology (Fig. 2). The SEM image clearly demonstrates that the catalyst particles have fibrous morphology, where CaO has an agglomerate of rod-like regular structure and the sawdust has fibrous morphology with lengths ranging from a few hundred nanometers to a few micrometers.

(a)



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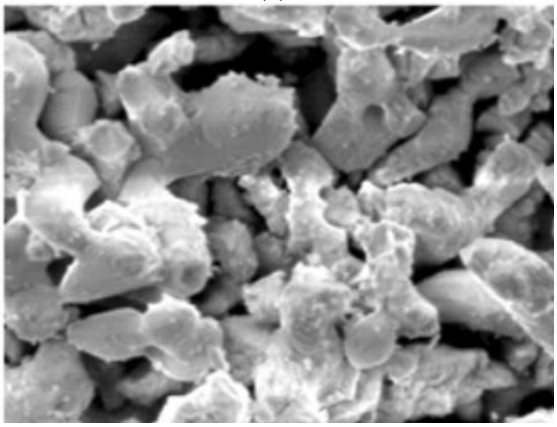

Figure 2: SEM for (a) Sawdust (b) CaO

BET surface area

The Surface Area (SA) of the catalyst considered to be significant parameters influencing catalytic activity. SA for sawdust was 13.79 m^2/g while for Cao 15.46 m^2/g.

Effect of oil to alcohol molar ratio

The percentage yield of alcohol biodiesel had been studied as a function of alcohol/oil molar ratio (moles of alcohol/moles of oil; 8:1, 12:1, 16:1, and 20:1). At a temperature of 65 Celsius, 0.5 % catalyst concentration, and 3 hrs of reaction time. In Fig. 3 , it has been shown that as the molar ratio was increased, the yield of biodiesel produced increased from 22 to 95% for CaO catalyst and 10.5 to 75% for the sawdust catalyst. As would be expected, this can be explained by the fact that increasing the alcohol content leads the reaction to spread to additional products. This behavior is consistent with the findings of Marwa and Ruqaya [13], who discovered that lauric acid conversion increased as the ethanol to acid molar ratio increased.

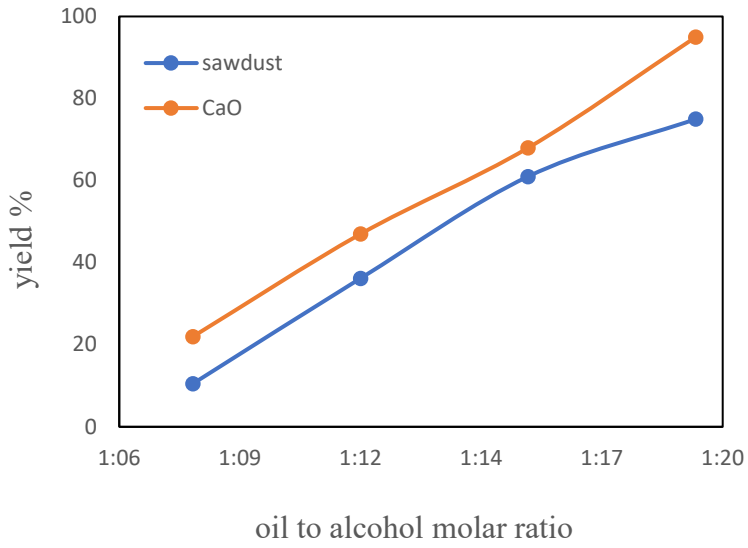

Figure 3: Effects of oil to alcohol molar ratio on yield of biodiesel at 65°C, catalyst concentration 0.5% and time 3h

Effects of catalyst amount

Transesterfication may involve the use of different catalyst concentrations. The effect of catalyst levels (at 65°C, alcohol/oil molar ratio (12:1) for 3 hrs) on percentage yield of the bio-diesel is shown in Fig. 4. Yield increased as the amount of the catalyst had been increased from (0.50-3)%, rising from (36-46)% and (47-63)% for sawdust and calcium oxide, respectively. Figure 3 illustrates that an optimum amount of catalyst of 3% could achieve a maximum percent yield of biodiesel of 63% using calcium oxide catalyst and 46% using sawdust catalyst. The adsorption process on the catalyst surface growing may be the cause of the increase in yield as the catalyst quantity increases. Kamisah et al.[14] show the same behavior in their study. Norshahidatul and Fatin [15] also noticed the yield increases as catalyst amount increased.

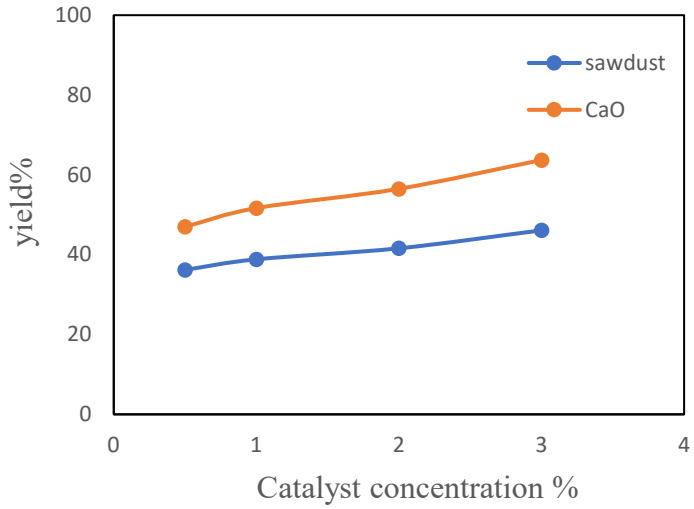

Figure 4: Effects of the concentration of the catalyst on yield of bio-diesel at temperature 65°C, oil to alcohol molar ratio1:12 and time 3h

Effect of temperature

Using CaO and sawdust catalysts, biodiesel is produced by combining ethanol and used cooking oil in a 1:12 mole ratio for 3 hours at different temperature degrees (45°, 55°, 65°, and 80°C). The impact of the temperature operation on biodiesel production is shown in fig. 5. The yield will rise to a specific point before starting to fall. The higher the temperature, the lower the viscosity of the oil and the faster the reaction. If the temperature rises above the ideal temperature, biodiesel production

will decrease because the alcohol concentration will decrease as the alcohol evaporates. The ideal temperature is around 55 degrees Celsius. At 45°C, sawdust and CaO catalyst yields were identified to be 32% and 52%, respectively, with yields increasing to 40% and 56% at a temperature of 55°C. The yield dropped to 36% and 47% for two catalysts at a temperature of 65 degrees Celsius. This behavior agrees with Sisca V. et.al [16] who used CaO catalyst.

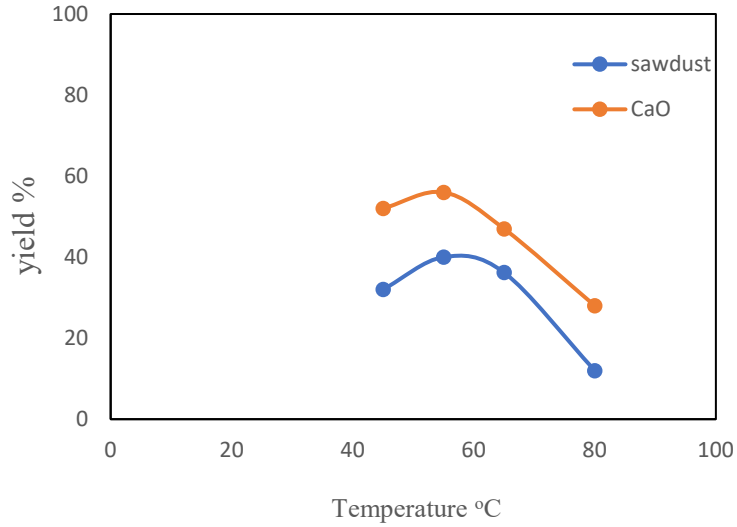

Figure 5: Effects of the temperature on yield of bio-diesel at catalyst concentration 0.5%, oil to alcohol molar ratio1:12 and time 3h

Effect of time

One of the most crucial factors influencing the conversion of biodiesel is thought to be the time of the reaction. The impact of time on production of biodiesel is shown in Fig. 6. With catalyst concentration of 0.5wt% and ethanol to oil molar ratio of 12:1, the reaction has been carried out at 65 °C. Following 0.5% catalyst concentration, 4 hrs of reaction time at 65°C, and 1:12 molar ratio of oil to alcohol, the highest conversion obtained using the catalyst CaO is 58%, while the maximum conversion that has been obtained using sawdust catalyst is 44%. This is brought on by a rise in the relative solubility of the produced glycerol in the reaction medium. The same behavior was also shwon by Sisca V. et.al [16].

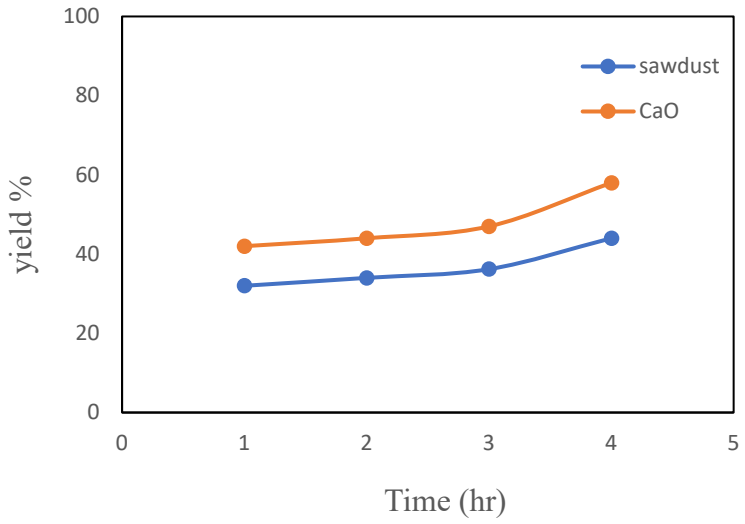

Figure 6: Effect of time on yield of biodiesel at catalyst concentration 0.5%, oil to alcohol molar ratio1:12 and temperature 65°C

Characteristics of produced biodiesel

The ASTM method was used to analyze the fuel characteristics of the acquired biodiesel generated by sawdust and CaO catalysts. As shown in Table 1, biodiesel made from ethanol demonstrated excellent fuel qualities that fell within parameters of the bio-diesel standard and were in good agreement with earlier findings [17] as well.

Table 1: Properties of biodiesel

Fuel properties	***Biodiesel***	**ASTM limits for B 100**
Flash point ^{o}C	155	100-170
Pour point ^{o}C	-9	-15-10
Cloud point ^{o}C	- 4	-3-12
Viscosity @40°C c.st	5.763	4-6
Density g/ml	0.878	0.86-0.9

Conclusions

This research showed that waste cooking oil could be utilized to make biodiesel, which may be utilized as alternative fuel in traditional diesel engines. The findings revealed that catalyst concentrations, ethanol to oil molar ratio, temperature of reaction, and reaction time all have an impact on bio-diesel production by transesterification with ethanol in the presence of two types of heterogeneous catalysts (CaO and sawdust). The best yield percentages of 75% and 95% have been obtained utilizing an ethanol: oil molar ratio of 20:1 as catalyst (0.5%) and 65^{o}C for 3 hours with the using sawdust and CaO catalyst, respectively.

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