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Influence of Eggshell as Heterogeneous Catalyst in the Production of Biodiesel Via Transesterification of Onion Oil

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Abstract

The global demand for energy is on the rise, driven by factors such as population growth and industrial expansion. Consequently, energy consumption worldwide is escalating steadily. This study investigates the catalytic efficacy of eggshells, specifically in the context of producing biodiesel from onion oil through transesterification. Two methods were employed: one utilizing sodium hydroxide as a homogeneous catalyst, and the other employing eggshells as a heterogeneous catalyst. Both reactions were conducted at 60-65°C for 60 minutes on a hot magnetic plate. The morphological properties of the eggshells were examined through SEM analysis, while XRF analysis was employed to assess their elemental composition. Results indicate that the use of eggshells as a catalyst yielded a maximum biodiesel percentage of 91.20% when 0.30 wt% of eggshell was utilized. These findings underscore the potential of eggshells as a viable heterogeneous catalyst in biodiesel production processes.

Keywords: *Eggshell, Onion oil, SEM, Transesterification, XRF*

1. Introduction

In recent years, the global energy landscape has been marred by a crisis stemming from the depletion of resources and escalating environmental challenges, largely attributed to the extensive use of fossil fuels (Ismail et al., 2022). This predicament is exacerbated by rapid population growth and industrial expansion (Barnwal & Sharma, 2005; Siddiqua et al., 2022). To address these concerns, there is a growing emphasis on harnessing renewable energy sources such as biodiesel, which offers significant advantages over conventional fossil fuels. Safeguarding the global environment and ensuring long-term fuel sustainability necessitate the development of alternative fuels on par with traditional options (Hassan et al., 2013; Hosseinzadeh et al., 2023).

Biodiesel, as described by Barnwal et al. (2005), comprises mono-alkyl esters of long-chain fatty acids derived from renewable sources like vegetable oils or animal fats, tailored for compression-ignition engines. It can be synthesized from a diverse range of feedstocks including common vegetable oils, animal fats, and waste cooking oils, both edible (such as soybean, sesame, and olive oil) and non-edible (like neem and jatropha oil) (Muhammad et al., 2023; Nura et al., 2023). Transesterification, also known as methanolysis, emerges as the preferred method for biodiesel production, wherein a catalytic reaction involving vegetable oil and alcohol yields biodiesel and glycerol (Jamo et al., 2023). This process entails replacing glycerol in triglycerides with a short-chain alcohol, leading to the sequential conversion of triglycerides into ester molecules (Banbafha et al., 2022; Zheng et al., 2020; Jamo et al., 2022).

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Onion (Allium cepa L.), a widely cultivated vegetable globally, serves not only as a culinary staple but also boasts medicinal properties. Onion oil, known for its therapeutic applications in treating various ailments, also exhibits fuel properties (Galavi et al., 2021). Despite extensive research on biodiesel production, there is *an inadequate* of studies exploring the catalytic potential of eggshells in utilizing onion oil.

Therefore, this study aims to assess the heterogeneous catalytic performance of eggshells in biodiesel production via transesterification of onion oil. This investigation fills a critical gap in the literature, offering insights into the viability of eggshells as a catalyst in biodiesel synthesis, particularly using onion oil as the feedstock.

2. Materials and Methods

This section outlines the materials and chemicals utilized in this research.

2.1 Chemicals

The materials and reagents employed in this study comprise crude onion oil, 8% sodium hydroxide (NaOH), 64% citric acid ($C_6H_8O_7$, purity: 99.7%), silicon reagent, activated carbon, eggshell, acetone, methanol, and distilled water.

2.2 Equipment

The instruments utilized in this investigation include a magnetic stirrer with a thermostatically controlled rotary hot plate (IKA C-MAG HS10), thermometer, measuring cylinder, digital weight balance (AND model GT2000 EC), beakers, conical flask, 24 cm filter paper, funnel, digital stopwatch, sampling bottles, spatula, X-ray Fluoroscopy machine, and SEM machine.

2.3 Methodology

The research methodologies applied in this study encompass SEM characterization of eggshell, transesterification, transesterification with the addition of eggshell as a catalyst, and X-ray Fluoroscopy analysis.

2.3.1 SEM Characterization of Eggshell

Eggshell SEM characterization was conducted using the multipurpose Scanning Electron Microscope model PHENOM PRO X MVE01570775. One gram of eggshell was subjected to scanning with a focused electron beam emitted by the machine. Through interaction with the eggshell's atoms, the electrons generated various signals revealing details about its surface topography and composition. The electron beam traversed in a raster scan pattern, with the beam's position synchronized with the intensity of the detected signals, ultimately resulting in the visualization of the eggshell's image (Stokes, 2008).

2.3.2 XRF Characterization of Eggshell

X-ray fluoroscopy characterization of eggshell was carried out using the ARL QUANT'X EDXRF Analyzer model (S/N 9952120). In this process, incoming X-rays emitted by the XRF machine displace electrons from the inner orbital of 1g of eggshell atoms, leading to their excitation and the generation of high-energy radiation, including photons, protons, and electrons. Subsequently, the emitted lines are detected and integrated to yield varying levels of intensity. Finally, these intensities are converted into elemental concentrations, which are then displayed on the monitor (Haschke, 2014).

2.3.3 Transesterification of Onion Oil

A quantity of 60 grams of onion oil was measured into a 250ml conical flask and subsequently heated and stirred to a temperature range of 60-65℃ on a hot magnetic stirrer plate. Meanwhile, 0.6 grams of NaOH was measured using an electronic weight machine, dissolved in 21ml of methanol, and then added to the oil mixture. The concoction was allowed to heat for 60 minutes with continuous stirring on the hot magnetic plate. Following a consistent stirring and heating period of 60 minutes while maintaining a temperature of 65℃, the mixture was carefully transferred into a separating funnel using a glass funnel. After approximately 40 minutes of cooling, the mixture segregated into two distinct liquid layers: the upper layer containing biodiesel and the lower layer containing triglyceride fatty acids (Ismail et al., 2022; Musa et al., 2022).

2.3.4 Transesterification of Onion Oil Using Eggshell as Catalyst

Using an electronic weighing machine, 60 grams of onion oil were accurately measured and poured into a 250ml conical flask. The mixture was then heated and stirred using a hot plate with a magnetic stirrer until it reached a temperature range of 60-65°C. Additionally, 0.6 grams of NaOH and 0.1 wt% eggshell were measured out and allowed to dissolve in 21ml of methanol. This solution was then added to the heated sample and allowed to heat for 60 minutes. Upon completion of this duration, the mixture was transferred into a separating funnel. After approximately 40 minutes of cooling, the sample separated into two distinct layers: the upper layer constituting biodiesel and the lower layer containing triglyceride fatty acids. The same procedure was replicated for eggshell concentrations of 0.2 wt%, 0.3 wt%, 0.4 wt%, and 0.5 wt% (Ismail et al., 2022).

2.3.5 Percentage of Biodiesel Yield

The percentage of biodiesel yield during the transesterification processes has been determined using the relation Equation (1) below (Ismail *et al.,* 2022).

$$Percentage\ of\ biodiesel\ yield = \frac{Mass\ of\ biodiesel\ produced}{Mass\ of\ oil\ used} \times 100\% \quad (1)$$

3. Results and Discussion

3.1 SEM Analysis of Eggshell

Figure 1 shows the SEM of eggshell which determined the morphology of eggshell.

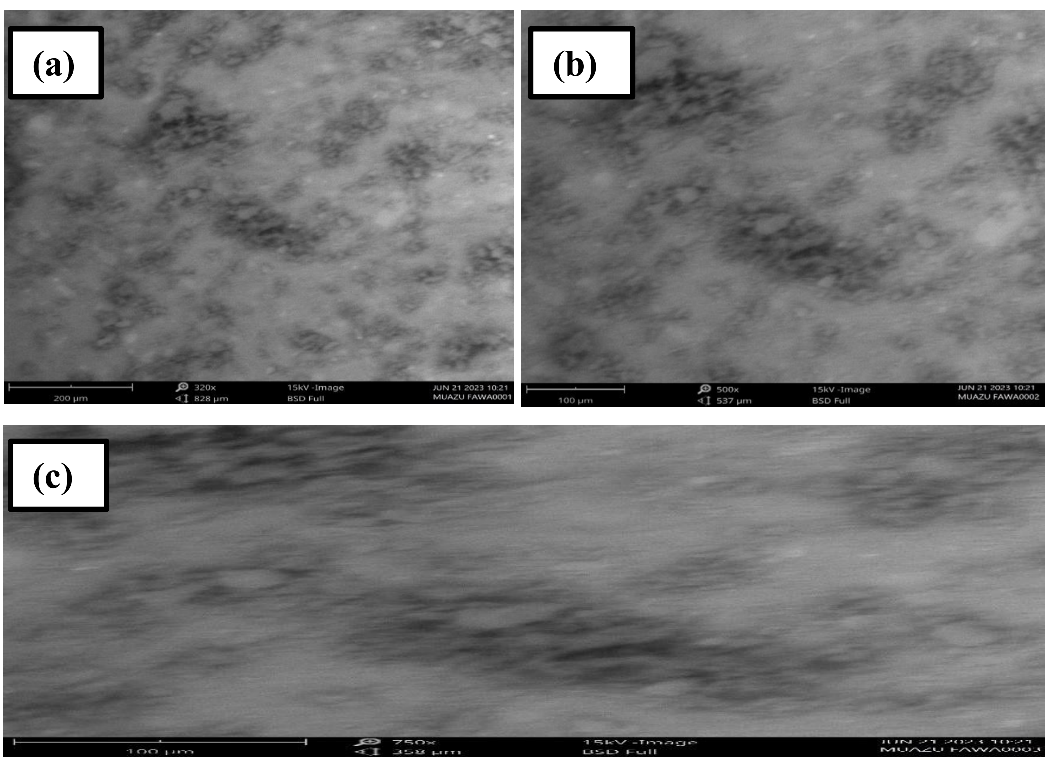

Figure 1: SEM of eggshell at the magnification of (a) 320x, (b) 500x and (c) 750x.

From Figure 1(a) to (c), the micrographs reveal the existence of dispersed particles and a cloud-like structure when observed at magnifications of 320X (200µm and 15KV), 500X (100µm and 15KV), and 750X (100µm and 15KV), respectively. These findings are similar to the results reported by Ismail *et al.,* (2022).

3.2 XRF Analysis of Eggshell

Table 1 presents the XRF analysis, revealing the compound composition of eggshell. According to the table, CaO constituted 94.119%, Na_2O 1.233%, SiO2 1.233%, MgO 0.665%, SO_3 0.566%, Al_2O_3 0.540%, Mn_2O_3 0.113%, Fe_2O_3 0.045%, SrO 0.013%, P_2O_5 0.012%, Others 0.534%, and Loss of Ignition 1.005%. It is evident that CaO holds the highest compound concentration in terms of percentage, while P_2O_5 exhibits the lowest concentration. This suggests that eggshell primarily consists of calcium oxide, rendering it suitable for use as a catalyst without posing environmental concerns. This finding aligns with previous studies by Buasri et al. (2013) and Ismail et al. (2022).

Table 1. XRF result of eggshell.

S/N	Compounds	Percentage concentration (%)
1	CaO	94.119
2	Na_2O	1.233
3	SiO_2	1.155
4	MgO	0.665
5	SO_3	0.566
6	Al_2O_3	0.540
7	Mn_2O_3	0.113
8	Fe_2O_3	0.045
9	SrO	0.013
10	P_2O_5	0.012
11	Others	0.534
12	Loss of ignition	1.005

3.3 Percentage of Biodiesel Yield

The percentage yield by the biodiesel by the addition of eggshell as catalyst is shown in the Table 2. Table 2 illustrates the biodiesel yield percentages obtained during the transesterification process of onion oil, both with and without eggshell serving as a heterogeneous catalyst, as determined by Equation 1. The findings highlight the significant impact of using eggshell as a heterogeneous catalyst on biodiesel yield. The percentage yield of biodiesel exhibited a steady increase from 0.00 to 0.30 wt% eggshell addition, reaching a peak of 91.20% at the 0.30 wt% mark. However, beyond this point, there was a tendency for the biodiesel yield percentage to decrease. These results closely align with those reported by Ismail et al. (2022).

Table 2. The percentage of yield biodiesel during the process.

Amount of catalyst use (wt%)	0.00	0.10	0.20	0.30	0.40	0.50
Percentage of biodiesel yield (%)	54.00	62.30	73.30	91.20	65.60	60.80

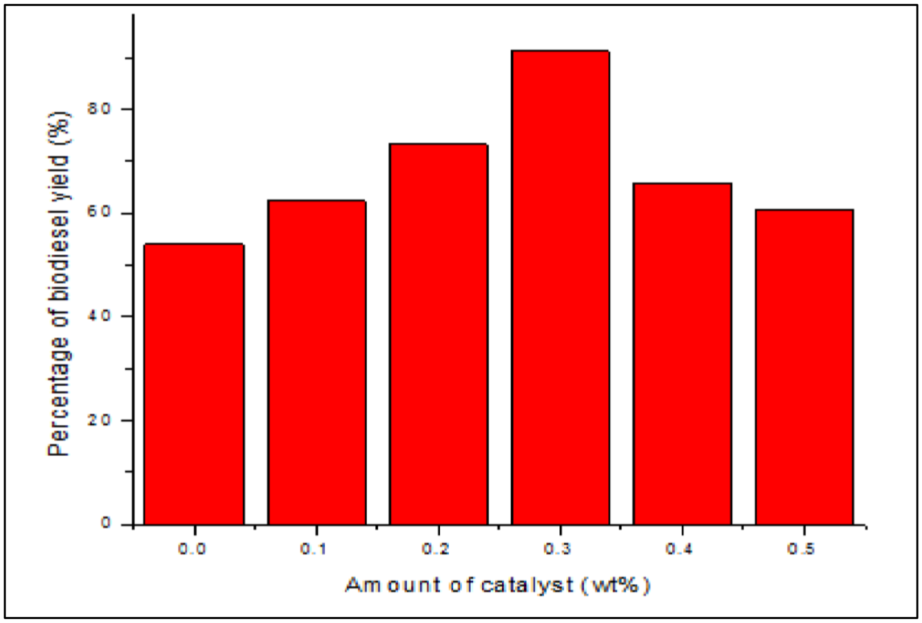

Figure 1: Percentage of biodiesel yield against amount of catalyst.

From Figure 1, it is evident that the percentage of biodiesel yield increased with the catalyst concentration until reaching 0.30 wt%. However, further increases in catalyst concentration led to a decrease in the percentage of biodiesel yield. This observation suggests that eggshell can effectively serve as a heterogeneous catalyst in the production of biodiesel via the transesterification of onion oil at a concentration of 0.30 wt%. Thus, eggshell plays a significant role as a heterogeneous catalyst.

4. Conclusion

An experimental study was conducted to investigate the effectiveness of eggshell as a heterogeneous catalyst in the transesterification of biodiesel using onion oil. XRF analysis of eggshell revealed that CaO constituted 94.119% among other elements. The findings of this research indicate that eggshell can serve as a catalyst when used with onion oil at a concentration of 0.3 wt%, resulting in the highest percentage of biodiesel. It is recommended to further explore the catalytic performance of eggshell using various types of oils.

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