Production and Characterization of Heterogeneous Catalyst (CaO) from Snail Shell for Biodiesel Production Using Waste Cooking Oil

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Abstract

The waste snail shell was screened to determine its efficiency as heterogeneous catalyst for biodiesel production via trans-esterification reaction. Prior to its use, the solid oxide material (shell) was calcined at 800°C for 4 h to convert CaCO3 to CaO. Physicochemical analysis of waste cooking oil reveals the acid value (3.47 mg KOH/gm), density (0.9 g/cm3), moisture content (0.1%) and kinematic viscosity (42.2) respectively. The prepared solid oxide catalyst was characterized using X-ray Fluorescence (XRF) and Fourier Transform Infrared Spectroscopy (FT-IR) methods. The catalytic activity of the catalyst was evaluated by the trans-esterification reaction under the following reaction conditions: temperature (60°C), time (3 h) and methanol to oil ratio (9:1) respectively. GC-MS analysis was used to characterize the fatty acid methyl ester composition. The research signified successful application of waste snail shell as heterogeneous catalyst for prospective economic preparation of heterogeneous catalyst. It also developed an unconditional avenue for using the waste snail shell as the catalyst.

Keywords: Biodiesel; Snail shell; Heterogeneous catalyst; Calcium oxide; Transesterification

Introduction

The 21st century is faced with many problems such as energy sustainability, environmental problems and rising fuel prices among others to mention but a few. Knowledge that is known about the usual conventional fuels is nothing to write good about as they are known for polluting air by emissions of sulfur dioxides, carbon-dioxides, particulate matter and other gases which are detrimental to the environment as it contributes to global warming problems [1] Even with this, we are still charged with the responsibility of harnessing energy from other green sources because "Energy sources are the main driver of economic growth and social development of a country" [2] and if we want to progress as a country, it is of paramount important that we should search for a greener alternative source of energy. Naveen [3], also noted that there is an exponential increase in the consumption of fossil fuel both in developed and developing nations; and it is estimated that these fuels shall be exhausted by the turn of 22nd century. This is an enough convincing reason to why research should be focused on an alternative source of energy.

The demand for world energy continues to rise due to two main reasons; the continuing increase in the world population and the growing demand by developing countries for their growth [2]. One of the alternative fuels, developed over a century ago is biodiesel. Biodiesel has been selected as an interesting alternative fuel as it is renewable, biodegradable, non-toxic and environment-friendly. Biodiesel possesses a high flash point, better lubrication and high cetane number and has a quite resemblance in regard to physical and chemical characteristics with that of conventional diesel fuel [4]. Vegetable oil and animal fat are the best sources for biodiesel [5]. These sources can be subjected to trans-esterification reaction to undergo change in viscosity and volatility. The transesterification is carried out with a simple alcohol in the presence of a catalyst, which can be either homogeneous or heterogeneous [6]. Transesterification can be catalyzed by an acid, base, or enzymes [7].

Heterogeneous catalysts have the advantage that separation and regeneration of the catalyst are easy and cheap [8]. Heterogeneous basic catalysts include alkaline earth metal oxides such as calcium oxide (CaO), magnesium oxide (MgO) and hydrotalcites [9]. Unfortunately, the preparation of heterogeneous catalyst is quite expensive and complex [10]. Therefore, low cost solid wastes are looked into to serve as solid heterogeneous catalysts. Several researches have been done on waste food materials like chicken egg shell, oyster shell, mud crab shell, golden apple snail, merretix venus and mollusk shell as cheap and abundant resources of CaO for application as low cost heterogeneous catalyst for biodiesel synthesis [11]. Egg shell has proved to be an active solid catalyst, providing yields of 96% [11] and 97%-99% [10]. Further, crab shell provided 97% of conversion [6] and snail shell provided a biodiesel yield of 87.28% [7]. In this work, we have carried out transesterification using the snail shell as inexpensive and environmentally-friendly catalyst. The aim was to optimize the process for biodiesel production from waste cooking oil using CaO catalyst.

Experimental

Materials

The used oil sample was taken from the fryer which was used for frying potatoes and other vegetables based food in Sokoto State. The used vegetable oil was mainly contaminated with water and solid particles. Some analyses (Table 2) were conducted on the waste oil to determine the quality of the oil and a pre-treatment process was conducted to remove the solid impurity through filtration. The snail...
Preparation and characterization of snail shell waste-derived catalyst

CaO catalyst was prepared by calcination method. The dried snail shell (100-200 mesh) was calcined at 800°C in air atmosphere with a heating rate of 10°C/min for 4 h. The product was obtained as a white powder. The calcined sample was kept in close vessel to avoid the oxidation of the sample. The calcined sample was kept in close vessel for 4 h before used. Figure 1 illustrates the preparation process of snail shell CaO catalyst. The yield was calculated as follows:

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\text{Yield} (%) = \frac{\text{Weight of biodiesel}}{\text{Weight of oil}} \times 100
\]

Results and Discussion

Physicochemical analysis of the WVO

The composition of the waste vegetable oil was analyzed, with the results obtained shown in Table 2. The amount of FFA in the oil was found to be 1.73%. Studies have shown that high FFA reduces the catalyst effectiveness and decreases the production yield; therefore, the recommended amount of FFA in WCO should not exceed 1 wt% [12]. In contrast, Ngoya et al. [13] stated that heterogeneous catalysts have proven to catalyze oil with high FFA content (6-15%) without any pre-treatment. The physical properties, like the specific gravity, density, free fatty acid content, moisture content, odor, color are presented in Table 2.

Catalytic testing

The trans-esterification reaction was performed in a 2000 cm² 4-necked round bottom flask. One of the side necks was fitted with a water-cooled condenser, the middle neck was used to insert magnetic stirrer, the desired amount of catalysts (CaO catalyst as much as 9% of the mass of the oil), methanol and waste frying oil was introduced into the round bottomed flask and the third neck was fitted with a temperature indicating thermometer and the reactions were carried out at 60°C for 3 h. After the reaction was completed, the mixture was allowed to settle overnight for the clear separation of biodiesel and glycerol as seen in plate 1 (Figure 2).
below in Figure 3.2. Traces of carbonate can be found between 1250 cm\(^{-1}\)-1600 cm\(^{-1}\), which might be adsorbed during sample preparation and afterwards trapped inside the oxide during the calcination process. The strong band at 3640 cm\(^{-1}\) corresponds to the O-H bonds and this is similar to a report made by Park et al. [14]. The absence of a sharp absorption in the region around 724 cm\(^{-1}\) to 924 cm\(^{-1}\) indicates that CaCO\(_3\) as the basic components of the snail shell is no longer present as it has already been converted to CaO [15].

**Biodiesel composition**

The analysis of the GC-MS shows there are about sixteen main characteristic peaks of Fatty Acids Methyl Esters (FAMEs) appearing by the retention time and the fragmentation pattern data of the biodiesel. See Figure 3.3 below.

The chemical composition of each peaks is shown below with 9-Octadecenoic acid, methyl ester (E), Hexadecanoic acid, methyl ester, 9, 12-Octadecadienoic acid (Z, Z)-, methyl ester and methyl stearate having the highest peaks.

**Name of the FAMEs**

- Octanoic acid, methyl ester
- Dodecanoic acid, methyl ester
- Diethyl phthalate
- Methyl tetradecanoate
- Tridecanoic acid, methyl ester
- 9-Hexadecenoic acid, methyl ester, (Z)-
- Hexadecanoic acid, methyl ester
- 3, 6-Dimethoxy-2, 5-dinitrobenzaldehyde oxime
- Heptadecanoic acid, methyl ester
- 9, 12-Octadecadienoic acid (Z, Z)-, methyl ester
- 9-Octadecenoic acid, methyl ester, (E)-
- Methyl stearate
- Oxiraneoctanoic acid, 3-octyl-, methyl ester, cis
- Oxiraneoctanoic acid, 3-octyl-, methyl ester cis-11-Eicosenoic acid, methyl ester
- Methyl 18-methylnonadecanoate
- Docosanoic acid, methyl ester
- Tetracosanoic acid, methyl ester.

The viscosity of the produced biodiesel methyl esters measured at 40°C was found to be 4.5 mm\(^2\)/sec for the biodiesel, which was in the range recommended by EN 14214 and ASTM D445. The EN 14214 standard for biodiesel viscosity is 3.5 mm\(^2\)/sec to 5.0 mm\(^2\)/sec at 40°C, while the ASTM D445 standard for biodiesel viscosity is 1.9 mm\(^2\)/sec to 6.0 mm\(^2\)/sec at 40°C.

**Biodiesel yield**

The snail shell-CaO produced a volume biodiesel conversion of 84.14%.
Conclusion

In the research presented herein, snail shell waste was used as catalyst for the production of the biodiesel process. The shell contained CaCO₃, which was converted to CaO after calcination at temperatures 800°C for 4 h and CaO was acknowledged as an effective heterogeneous catalyst for the transesterification of waste cooking oil. The optimal reaction conditions used in this research, which yielded a conversion of 84.14% biodiesel, were: reaction time 3 h, reaction temperature 60°C, methanol to oil molar ratio 9:1 and catalyst concentration 9% wt of oil. The experimental result showed that CaO catalyst derived from snail shell had an excellent activity and as a heterogeneous catalyst from waste shell, it can reduce the cost of biodiesel production. Similarly, it proved to be a potential feedstock for industrial application.

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