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Alternative Biodiesel Production from Garviola Seed Oil using Carbonized Wood Ash as Heterogeneous Catalyst for Environmental Control

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Abstract
This study examines the synthesis of biodiesel from the waste seed oil of Garviola as a substitute for conventional diesel, in response to the escalation of global warming and the continuous rise in fuel prices, which pose a significant threat to humanity.
The results indicated that the carbonized wood ash contained high concentrations of calcium and carbon, measuring 43% (wt./wt.) and 38% (wt./wt.), respectively. Biodiesel yields were significantly influenced by factors such as reaction time, reaction temperature, catalyst concentration, and the methanol-to-oil molar ratio, with a maximum yield of 95.20% (wt./wt.) achieved during experimental run 4, which involved a reaction time of 65 minutes, a reaction temperature of 60 °C, a catalyst concentration of 3.0 g, and a methanol-oil molar ratio of 6. The properties of the produced biodiesel met the recommended standards. Therefore, the study concluded that the synthesis of biodiesel from Garviola seed oil using a heterogeneous catalyst is feasible and environmentally friendly
Keywords: *Garviola seed; Biodiesel, Carbonized wood ash; Global warming; Biodiesel properties*

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I. Introduction

Burning fossil fuels releases the energy they contain, which propels smoke and other gasses into the atmosphere. Regrettably, burning fossil fuels has a negative impact on both humans and the environment by releasing dangerous particles and greenhouse gases into the atmosphere making it environmentally harmful. Fossil fuels are not replenished quickly enough for human usage indefinitely, which is why they are considered nonrenewable. Deep down in the earth, fossil fuels take millions of years to produce, and human need cannot wait for fresh coal to appear. Continuous use of fossil fuels at current rate will make the nation run out of the fuel. Hence the needs for alternative fuel such as fuel that have been reportedly produced from oils (Adepoju et al., 2020).

Oils generally can be obtained from agricultural seeds (Eyibio et al., 2022), fats from the lards (Jassinnee et al., 2017), and algae from the plants (Hadiyanto et al., 2021). Literature reviewed shows that using seed oils for biofuel production helps to solve disposal problem across the countries (Ozioko et al., 2024). These reason and some other reasons made the researchers source for agricultural wastes seed for biodiesel synthesis (Rambabu et al., 2023).

For a standard biofuel, the used of different catalysts have been reported, but heterogeneous solid base catalyst proved to have advantages over the other homogeneous and liquid base catalysts (Eko et al., 2022). In this study, biodiesel was produced from Garviola seed otherwise known as soursop seed (Fig. 1). The oil obtained from the seed was then converted to biodiesel using a solid heterogeneous catalyst developed from wood ash. The produced biodiesel properties were evaluated and were compared with biodiesel recommended standard.

(a) Garviola fruits **(b) Garviola seed**

Fig. 1: Garviola

II. Material And Methods

2.1 Materials

Freshly Garviola seed was obtained from local market in Omu Aran, Kwara State, the seed was sun-dried for 5 days and was manually cracked to obtained the fleshy part. The fleshy part was further oven dried at 80 ^oC until constant weight was achieved. This was further milled into powder and kept for further analysis.

Wood ash (WA) was obtained from the bakery; the WA was manually sorted out to remove the impurities, and was immersed in a beaker (1000 L) containing 500 mL of distilled water to remove the unwanted contaminants. The mixture was filtered and the filtrate was discarded while the residue was oven dried at 120 ^oC for 4 h. The dried residue WA was further carbonized in an oven at 400 ^oC for 3 h, and was allowed to cool at room temperature for further processes.

2.2 Methods

2.2.1 Oil extraction

Oil was extracted from Garviola milled seed using acetone due to its unique properties (Its physical properties include boiling point 56.2 ^oC, melting point −94.8°C). The extract of oil extracted was calculated using equation (1)

$$\textbf{Oil yield}\ (\%) = \left(\frac{\textbf{weight of oil}}{\textbf{weight of seed powder}}\right)\textbf{x100} \qquad (\mathbf{1})$$

2.2.2 Catalyst characterization

The carbonized wood ash was characterized using SEM-EDX and XRD analyzer so as to ascertain the morphological structure and the elemental compositions of the carbonized wood.

2.2.3 Biodiesel production

Biodiesel production was carried out using the modify method earlier reported by Adepoju et al. (2022). 100 mL of the oil was measured in a reactor, 2 g of carbonized wood ash was mixed with until it was dissolved, the mixture was transferred to the reactor oil and the reaction was allowed to complete at the temperature rate of 56 ^oC/50 min. At the end of reaction, the biodiesel was separated from the by-products (glycerol-catalyst) using downward gravity settling in the separating funnel. The purity of the biodiesel was ascertained by washing with distilled water, and dried over calcium chloride. The yield of biodiesel was determined using equation. (2):

$$\text{Biodiesel yield}\ \%\left({}^{\text{wt.}}/{}_{\text{wt.}}\right) = \left(\frac{\text{Weight of biodiesel produced}}{\text{Weight of oil used}}\right)\text{X100} \qquad (2)$$

2.2.4 Determination of physicochemical properties of biodiesel

The properties of biodiesel produced were examined by determining the properties of the sample using standard methods of AOAC 1999 and Wij's method. The results obtained were compared with recommended standard (with ASTM and EN).

III. Results And Discussion

3.1 Carbonized WA SEM analysis

Electrons are used in scanning electron microscopy (SEM) to create high-resolution images. It is the most effective method for examining the characteristics and form of solid polymers, plastics, and catalysts on their surfaces. The structural and morphological image of the carbonized WA (1000x mag.) acquired during the SEM analysis research is shown in Fig. 2. It was observed that the picture had a porous surface with spaces that enabled the catalyst's activities to quickly generate biofuel during the transesterification reaction. Its perspective is broken, and its colour is also whitish-black. The use of oven-treated in a furnace heat treatment is responsible for this.

The catalyst's heterogeneous atoms, which give its porous voids their forms and sizes, are produced by a thorough breakdown. The hue suggested that during the calcinations, ash had been produced at a high temperature.

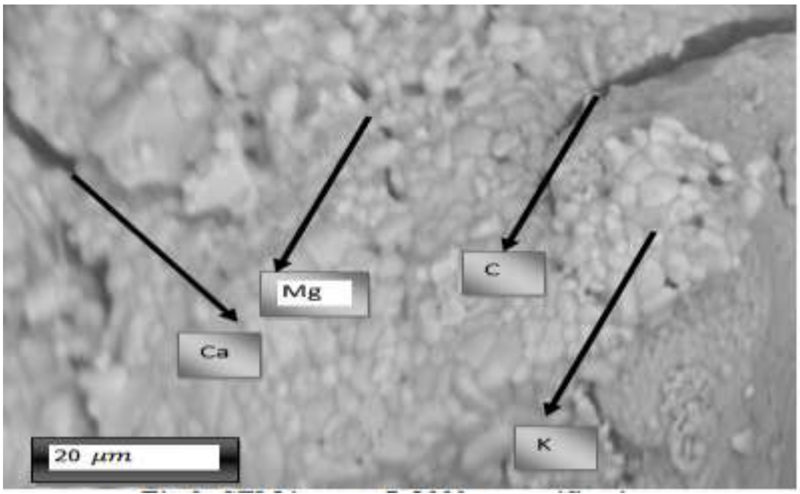

Fig.2: SEM images @ 1000x magnification

3.2 Carbonized WA XRD analysis

The carbonized WA XRD analysis data, shown in Fig. 3, show that the heterogeneous catalyst used in the conversion of oil to biodiesel contains elemental minerals. Although the concentrations of these salts vary, calcium (ca) was the most noticeable element with high concentration. The orders of high concentration were as indicated: Ca>C> K>Mg>Mn>P>Na in descending order. These materials are constantly stable (non-expanding and charge imbalanced) and have the ability to absorb the excess water in oil during the biodiesel production stage.

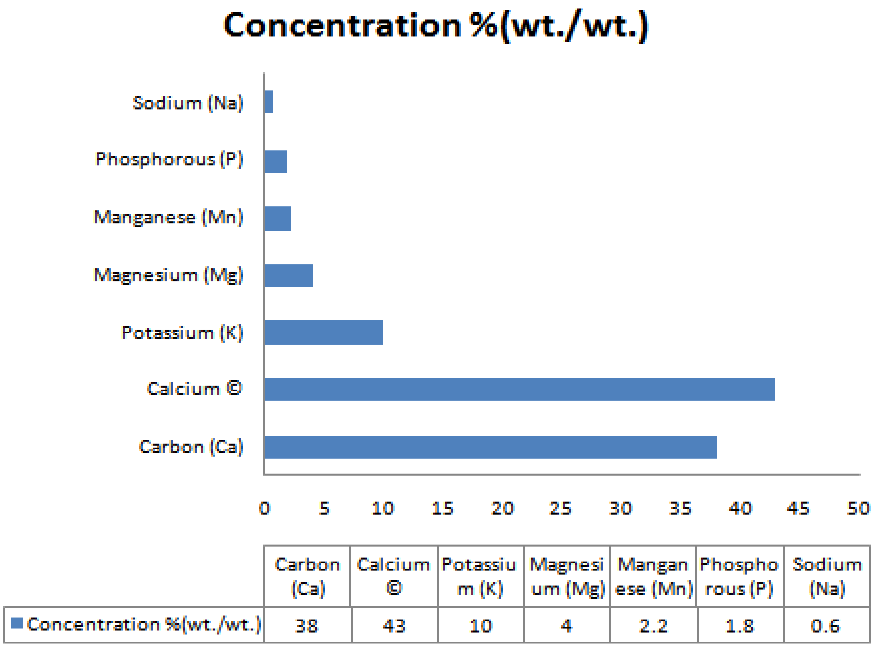

Fig. 3: XRD analysis of the carbonized WA

3.3 Biodiesel production

Biodiesel synthesis was carried out in five replicate processes considering the key factors as indicated in the Table 1. The yield of biodiesel at each varied variables were also presented. It was observed that the highest yield of 95.20 %(wt./wt.) was obtained at experimental runs 4 at reaction time of 65 min, reaction temperature of 60 ^oC, catalyst concentration of 3.0 g , and methanol-oil molar ratio is 6. This is an indication that twice methanol-oil molar ratio produced maximum biodiesel yield when compared with stoichiometric reaction of esterification reaction (Babatunde et al 2025).

Table 1: Variables and biodiesel yields

Experimental	Reaction time (min)	Reaction temperature (^oC)	Catalyst concentration %(wt. /wt.)	Methanol-oil molar ratio	Yield biodiesel %(wt. /wt.)
1	50	45	1.5	3	**85.40**
2	55	50	2.0	4	**90.80**
3	60	55	2.5	5	**94.30**
4	65	60	3.0	6	**95.20**
5	70	65	3.5	7	**94.70**

3.4 Properties of biodiesel

The properties of biodiesel produced were as given in Table 2. It was observed that the properties of produced biodiesel conformed with biodiesel recommended standard and the fuel is good with low emission properties making it suitable as alternative to conventional diesel.

Table 6: Properties of KSOB and the literatures data

Parameters	Biodiesel	ASTM D6751	EN 14214
Density (kg/m^3) @ 40 ^oC	880	-	860-900
Viscosity @ 40 ^oC/ (mm^2/s)	3.90	1.9-6.0	3.5-5.0
Moisture content (%)	0.01	<0.03	0.02
%FFA (as oleic acid)	0.24	0.40 max	0.25 max
Acid value (mg KOH/g oil)	0.48	0.80 max	0.5 max
Iodine value (g I_2/100g oil)	108	-	120 max
Saponification value (mg KOH/g oil)	158	-	-
Peroxide value (meq. O_2/kg oil)	8.20	-	12.85
HHV (MJ/kg)	41.33	-	-
Cetane number	56.54	57 min	51 min
API	29.30	39.95 max	-
Diesel index	64.64	50.4 min	-
Cloud point (^oC)	7	9 min	-
Flash point (^oC)	135	50 min	-
Pour point	-8	-2	-28

IV. Conclusions

From the study, it can be concluded that the conversion of Garviola seed to oil for biodiesel synthesis was visible. The catalyst synthesized from wood ash was found to be rich in carbon and calcium contents, making it a right choice as a bio base for biodiesel production. The produced biodiesel properties conformed with recommended biodiesel properties. Hence, the biodiesel is environmental friendly.

Declarations

Ethics approval and consent to participate

Not Applicable

Consent for publication

All authors consented and agreed to take part in this study as research participant.

Competing interests

Authors declares no competing interests whatsoever

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