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Cow Bone-Derived Materials as Catalysts for Biodiesel Production from Refined Palm Kernel Oil

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Abstract

This study examined the preparation and reported performance of a calcined cow-bone material in biodiesel production from refined palm kernel oil. Cow-bone material was cleaned, dried, processed, and calcined at 650 °C; the manuscript also reports X-ray diffraction, Fourier-transform infrared spectroscopy, X-ray fluorescence, and transmission electron microscopy analyses. Three reaction runs are tabulated with 60 mL of oil, 150 mL of methanol, a reported NaOH dosage of 2.5–7.5, and reaction times of 30–60 min. The reported biodiesel-yield values were 20.0, 12.0, and 8.5 mL, while product-yield values were 4.0, 4.0, and 2.2 mL. The material was reported to contain SiO_2, CaO, and Al_2O_3. However, the experimental description and several reported units and totals are inconsistent, and the tabulated yields do not substantiate the 58.32% yield stated elsewhere. The results should therefore be treated as preliminary pending verification of the protocol and underlying measurements.

Keywords: cow bone; heterogeneous catalyst; biodiesel; refined palm kernel oil; calcination; transesterification

1. Introduction

The search for renewable liquid fuels has increased as energy demand has grown and concerns about greenhouse-gas emissions have intensified. Biodiesel is a mixture of fatty-acid alkyl esters produced principally by transesterifying triglycerides with a short-chain alcohol in the presence of a catalyst (Ma & Hanna, 1999; Meher et al., 2006; Yusuf et al., 2011). Its feedstocks include vegetable oils, animal fats, and used cooking oils. Feedstock cost and the need to manage waste oils are important considerations in production (Mohammadshirazi et al., 2014; Talebian-Kiakalaieh et al., 2013).

Homogeneous base catalysts can promote rapid transesterification, but separation, soap formation, and wastewater management may complicate downstream processing. Heterogeneous catalysts can be separated from the reaction mixture and may be reused, although their performance depends on composition, preparation, and reaction conditions (Helwani et al., 2009; Lee et al., 2014). Animal bones contain calcium-phosphate minerals and have been investigated as low-cost catalyst precursors. Calcined cow-bone materials have been studied in biodiesel production from soybean oil, while calcined animal bones have also been reported for palm-oil transesterification (Ayodeji et al., 2018; Obadiah et al., 2012).

Refined palm kernel oil was selected as the feedstock in this study. Prior work on bone-derived catalysts provides a basis for evaluating this material, but catalyst performance cannot be generalized across feedstocks or preparation protocols (Hussain et al., 2021). The study therefore examined the preparation and characterization of calcined cow-bone material and documented the reported biodiesel yield and selected fuel properties for reactions using refined palm kernel oil.

The study aimed to (1) prepare a cow-bone-derived material by thermal treatment, (2) report its elemental and structural characterization, and (3) document biodiesel yield and selected properties under the reaction conditions described by the authors.

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2. Materials and Methods

2.1 Cow-Bone Material Preparation

The source manuscript describes a wet-impregnation procedure in which processed bone material was suspended in deionized water, mixed for 4 h at room temperature, and evaporated on a hot plate at 50 °C for 30 min and then at 70 °C for 30 min. The dried material was calcined in a muffle furnace at 650 °C for 4 h under airflow. The mass of bone, water volume, impregnation reagent and concentration, drying endpoint, furnace ramp rate, and cooling conditions were not reported. Figure 1 shows the bone material and the resulting calcined powder.



Figure 1. Cow-bone material before and after processing.

2.2 Chemicals and Feedstock

Anhydrous methanol (99.8%) was obtained from Doubara Scientific Instruments Nigeria Ltd. Refined palm kernel oil was obtained from Bayelsa Palm Nigeria. The manuscript also lists sodium hydroxide, sulfuric acid, distilled or deionized water, and calcined cow-bone material. Figure 2 presents the materials shown in the supplied photographs.

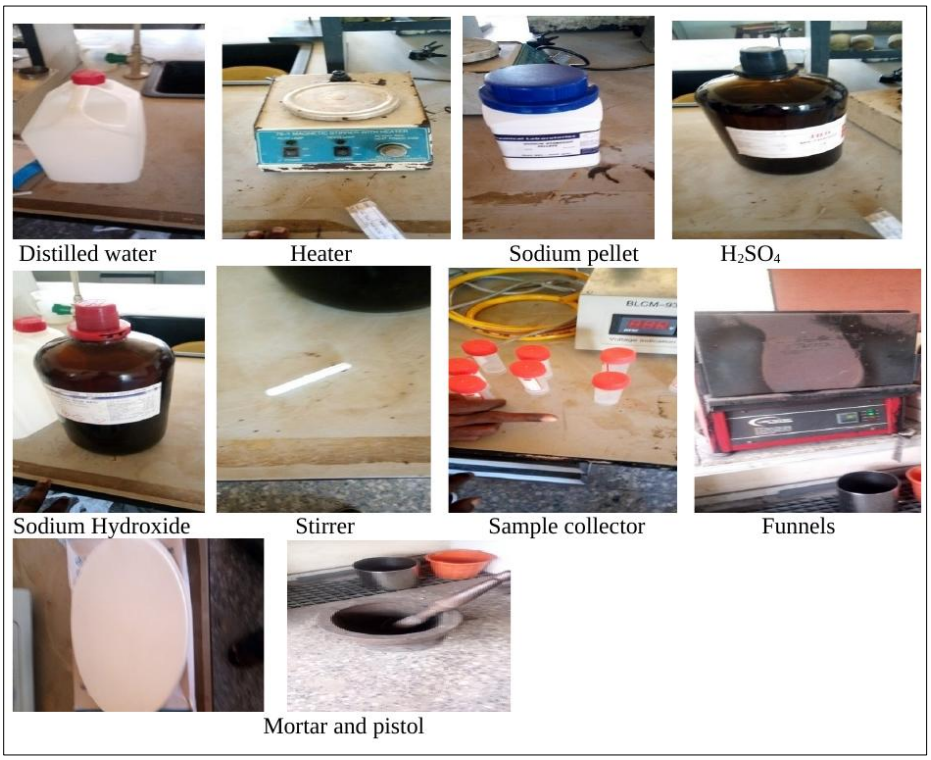


Figure 2. Chemicals and materials shown for catalyst preparation.

2.3 Reaction Procedure

The source manuscript reports the use of anhydrous methanol, refined palm kernel oil, sodium hydroxide, and calcined cow-bone material. It describes reaction runs using 60 mL of oil and 150 mL of methanol, with reaction times of 30, 45, and 60 min. It also describes heating a methanol-containing mixture to approximately 60 °C and subsequent separation by centrifugation. The source does not consistently state the catalyst identity, dosage units, reaction temperature, alcohol-to-oil molar ratio, order of addition, centrifugation conditions, washing and drying steps, or the method used to calculate biodiesel yield. These details must be confirmed from laboratory records. The apparatus shown in the photographs is presented in Figure 3.



Figure 3. Experimental setup reported for biodiesel production from refined palm kernel oil.

2.4 Characterization and Fuel-Property Measurements

The source reports X-ray fluorescence (XRF), X-ray diffraction (XRD), Fourier-transform infrared (FTIR) spectroscopy, and transmission electron microscopy (TEM). Instrument models, operating conditions, sample preparation, calibration procedures, and the methods used to measure fuel properties were not provided.

2.5 Biodiesel Standards

The source manuscript refers to the Australian Standard, EN 14214, and ASTM D6751. These standards specify fuel-quality requirements and test methods for biodiesel. Table 1 summarizes the standards as listed in the source; standard editions and applicability should be verified before submission. The manuscript does not identify which test method was used for each reported property.

Table 1. Biodiesel standards listed in the source manuscript.

Country	Region /Standard	Date	Applicable to
Australia	Australian Standard	2003	FAME
European Union	EN14214	2003	FAME
USA	ASTM D 6751	2003	FAME

3. Results

Three reaction runs and the reported characterization results are summarized below. Values are transcribed from the supplied tables; inconsistencies are considered in the Discussion.

3.1 Reported Biodiesel and Product Yields

At a reported calcination temperature of 650 °C, biodiesel-yield (BDY) values were 20.0, 12.0, and 8.5 mL, and biodiesel-product-yield (BPY) values were 4.0, 4.0, and 2.2 mL for the three runs. The table lists 60 mL of palm kernel oil and 150 mL of methanol for each run, with a reported NaOH dosage increasing from 2.5 to 7.5 and reaction time increasing from 30 to 60 min. The combined values are reported as 40.5 mL BDY and 10.2 mL BPY (Table 2).

Table 2. Reported reaction conditions and biodiesel yields; 650 °C is the reported calcination temperature.

Palm kernel oil (ml)	Catalyst (NaOH) (gmol)	Time (min)	Methanol (ml)	Calcinated temperature (ToC)	BDY biodiesel yield (ml)	BPY biodiesel product yield (ml)
60	2.5	30	150	650	20.00	4.00
60	5.0	45	150	650	12.00	4.00
60	7.5	60	150	650	8.50	2.20
Total yield					40.50	10.20

3.2 Reported Density and Fuel Properties

The reported operating conditions and density measurements are shown in Table 3. The source gives density values of 0.025, 0.024, and 0.025 g/mL for runs A–C, respectively.

Table 3. Reported run conditions and density values.

Run	Sample	Agitation RPM	Catalyst dosage	Catalyst temp (oC)	Time (min)	Density (g/ml)
1	A	400	2.5	650	30	0.025
2	B	500	5.0	650	45	0.024
3	C	600	7.5	650	60	0.025

The source reports a density range of 0.024–0.025 g/mL and a viscosity value of 7.40 in the property table. The table also lists cloud points of −34 °C, pour points of −18 °C, flash points of 124 °C, acid numbers of 0.07 mg KOH/g, octane number of 0.84, and a combined pH/calorific-value entry. These values and units are reproduced in Table 4 as reported.

Table 4. Reported fuel properties of the biodiesel samples.

Viscosity (mpd)	Cloud point (oC)	Pour point (oC)	Flash point (oC)	Acid number (mgkoH/g)	Octane number (%)	PH values (65oC)/CV (kj/kg)
7.40	-34	-18.0	124	0.07	0.84	5.6/5.324
7.40	-34	-18.0	124	0.07	0.84	5.6/5.324

Viscosity (mpd)	Cloud point (oC)	Pour point (oC)	Flash point (oC)	Acid number (mgkoH/g)	Octane number (%)	PH values (65oC)/CV (kj/kg)
7.40	-34	-18.0	124	0.07	0.84	5.6/5.324

The manuscript's narrative gives broader ranges for some properties, including viscosity, flash point, and acid number, but the corresponding table repeats the same entries across all three rows. The available record does not explain these differences or identify replicate measurements; therefore, variability and sample-to-sample comparisons cannot be assessed from the supplied information. Several units and entries are incomplete or inconsistent, so no compliance conclusion is drawn.

3.3 XRF, XRD, FTIR, and TEM Characterization

The XRF table reports mole percentages of 54.61% SiO_2, 12.01% CaO, 13.06% Al_2O_3, and 0.00% MgO (Table 5). The listed components sum to less than 100%, and the table does not indicate whether other components were omitted.

Table 5. XRF composition values reported for calcined cow-bone material.

Bones	Component	Surface Density (mg/cm²)	Mole percent
Cow	SiO_2	51.19	54.61
Cow	CaO	10.51	12.01
Cow	Al_2O_3	20.77	13.06
Cow	MgO	0.00	0.00

The supplied XRD diffractogram is shown in Figure 4. The source manuscript assigns peaks to silica-, calcium-, and aluminium-containing phases, but does not provide enough methodological detail for independent verification.

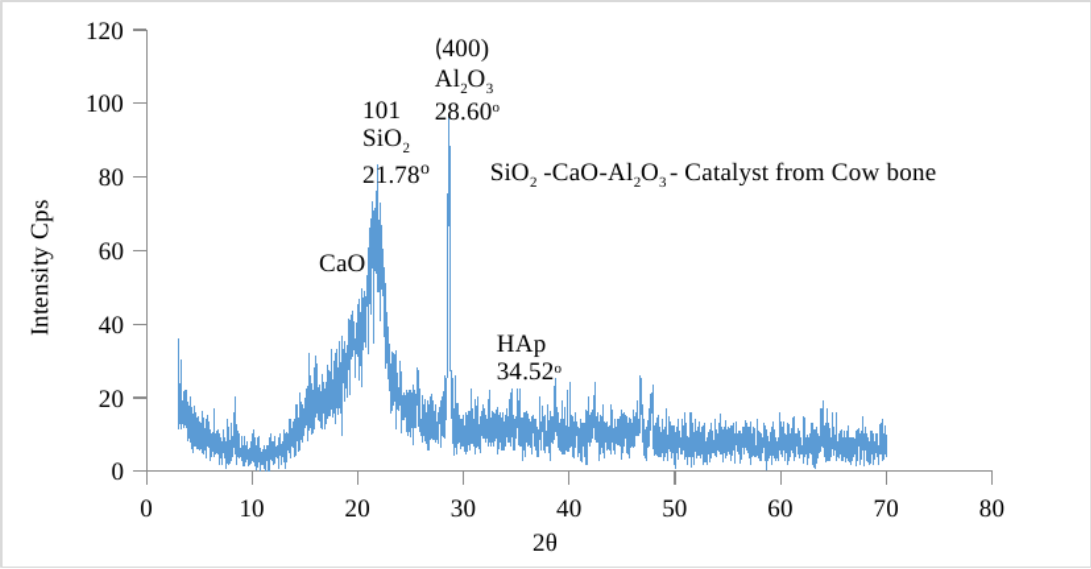


Figure 4. XRD diffractogram of calcined cow-bone material.

The supplied FTIR spectrum is shown in Figure 5. The source manuscript interprets features as hydroxyl-, carbon–hydrogen-, carbonyl-, silicon–oxygen-, aluminium–oxygen-, phosphate-, and calcium–oxygen-related signals; these assignments require verification against the spectrum and analysis protocol.

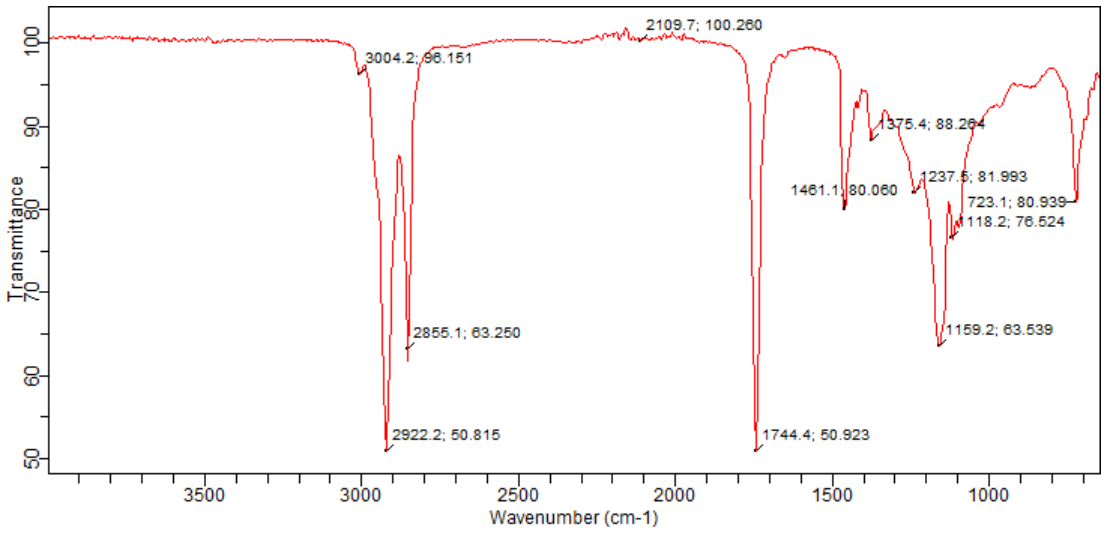


Figure 5. FTIR spectrum of calcined cow-bone material.

The supplied TEM micrograph is shown in Figure 6. The image contains particle-size labels of approximately 8–10 nm, but no sampling or image-analysis method was reported.

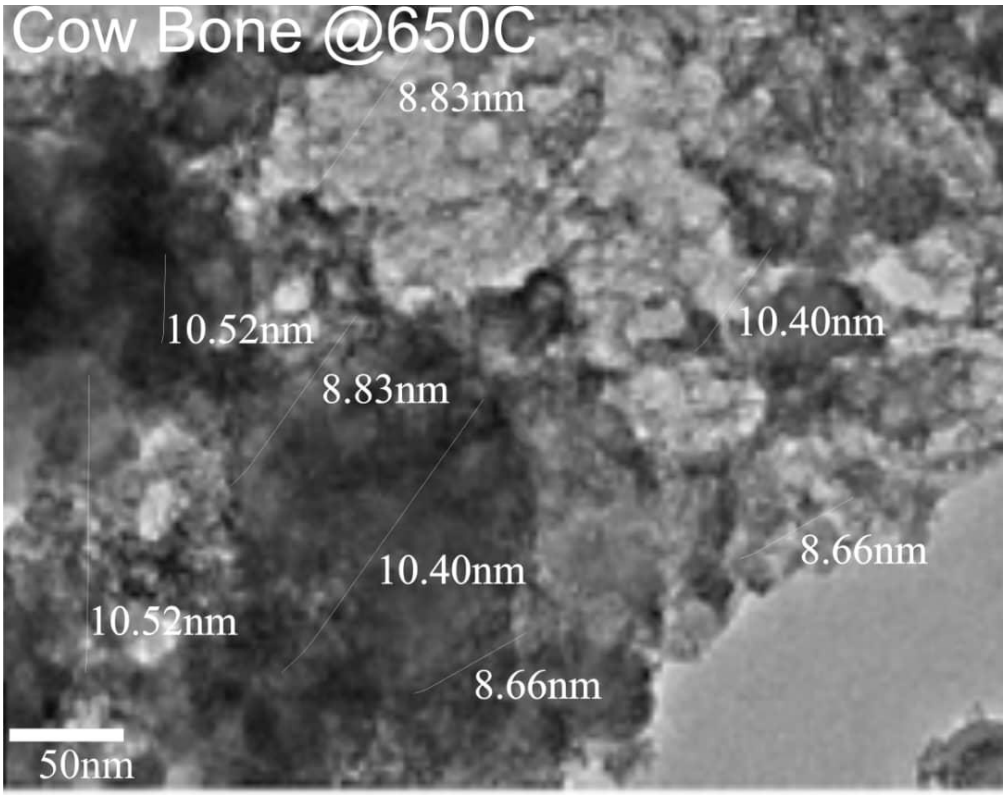


Figure 6. TEM micrograph of calcined cow-bone material.

4. Discussion

The tabulated yield values decrease across the three runs as the listed NaOH dosage and reaction time increase. Because these conditions changed together, the data do not isolate the effect of catalyst dosage or reaction time. The manuscript also alternates between describing NaOH and calcined cow-bone material as the catalyst. The yield table therefore cannot establish the performance of a cow-bone-derived catalyst without confirmation of the catalyst used in each run and the basis of the yield calculation.

The reported material characterization is consistent with the presence of several mineral components, but the XRF percentages are incomplete as presented and the XRD, FTIR, and TEM analyses lack enough procedural detail for independent verification. The reported density and calorific-value units are also not sufficiently documented, and the abstract and conclusion in the source contain yield and property values that do not match the tables. These issues prevent a reliable comparison with published catalyst performance or fuel standards.

A repeat study should use a clearly specified catalyst, independently vary reaction conditions, include replicate runs, and report uncertainty. The authors should verify the laboratory records, units, yield calculations, and instrument outputs before making quantitative performance or commercialization claims. Engine-performance testing and biodiesel–diesel blend trials may be considered after the fuel composition and quality measurements have been verified.

5. Conclusions

The supplied manuscript documents preparation of a cow-bone-derived material calcined at 650 °C and reports preliminary biodiesel-yield and characterization results for refined palm kernel oil. The tabulated yields and property measurements are not internally consistent with the abstract, narrative, or conclusion, and the reaction procedure does not identify the catalyst and dosage consistently. The current record therefore supports only a preliminary account of the work; the authors should verify the experimental protocol and underlying data before drawing conclusions about catalyst effectiveness, fuel quality, or commercial potential.

Authors Contribution

Opara Victor Samuel: Conceptualization, methodology, investigation, data curation, formal analysis, visualization, and writing—original draft. Kotingo **W. Kelvin**: Supervision, validation, resources, project administration, and writing—review and editing. Both authors read and approved the final manuscript.

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Data Availability Statement

Available on reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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