CATALYTIC PERFORMANCE OF NANO-CALCIUM OXIDE (N-CAO) FROM DIFFERENT WASTE BONES AND COOKING OILS IN BIODIESEL PRODUCTION

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ABSTRACT

The trans-esterification procedures of refined waste groundnut oil (WGO) and sunflower oil (WSO) were optimized using calcium oxide obtained following combustion and analysis from three distinct animal bones. The bone samples were crushed and calcined at 600 °C into fine powders with particle dimensions of 49 nm. The transmission electron microscope (TEM), scanning electron microscopy (SEM), X-ray diffraction (XRD), X-ray fluorescence (XRF), Brunnar Emmet Teller (BET), and Fourier transform infrared spectroscopy (FTIR) techniques were used to characterize calcined bones such as calcined fish bone (CFB), calcined cow bone (CCB), and calcined chicken bone (CCHB). To make methyl ester, powdered calcium oxide (CaO) was extracted from discarded animal bones (FAMEs). The influence of the catalyst dosage ratio on the physicochemical parameters of the produced biodiesel, such as yield, specific gravity, density, kinematic viscosity, and acid values, was researched and evaluated. The analysis of findings using the Statistical Package for Social Sciences (SPSS software) revealed that groundnut-based biodiesel (GNB) with CCB at 3.0 wt. % yielded 95.0 %, followed by sunflower-based biodiesel (SFB) with CCB 4.0 wt. % yielded 95.0 %. The best ideal trans-esterification reaction parameters were a 1:6 molar oil-to-methanol ratio, a 1 hour reaction period, a 333 K reaction temperature, a 1000 rpm stirring rate, and a 3-4 wt. %t CaO catalyst loading. This study discovered that waste cooking oils and the calcium oxide derived from them were excellent sources of materials that can improve biodiesel production and meet American criteria for testing materials ASTM requirements

KEYWORDS: Catalytic performance, Trans-esterification, Optimisation, Calcium oxide, Biodiesel

INTRODUCTION

Every nation's economic growth is heavily dependent on its energy supply. Energy is needed by sectors of the economy like commerce, transportation, industry, agriculture, and the main energy sources are fossil fuels like coal, natural gas, and petroleum. Fossil fuel combustion has increased environmental contamination issues as a result of widespread use of fossil fuels in home and industrial operations [1-3].

The phrase "waste cooking oil" merely means that the edible oil has been exposed to prolonged high-temperature frying and is no longer suitable for use in a similar manner. Most cities in developing nations discharge used cooking oil into the environment, creating problems for the environment, human health, society, and the economy [4]. The biodiesel produced from refined used cooking oil delivers environmentally beneficial fuel with minimal hazardous gas emissions, including SOx and NOx. The production of biodiesel from used cooking oil benefits the environment, the economy, and waste management. Solid catalysts have received a lot of

attention recently for use in the manufacture of biodiesel [5]. Heterogeneous catalysts have to be developed due to some restrictions, including the loss of biodiesel during washing, the inability of catalyst reuse, and the need for exact separation methods. The purpose of this study is to assess the trans-esterification process' catalytic efficacy of calcium oxide derived from various waste sources (cow, chicken, and fish bones).

MATERIALS & METHODS

2.1 MATERIALS EXTRACTION AND CAO NANOPARTICLE PREPARATION FROM CHOSEN ANIMAL WASTE

In Nigeria's Kwara State, Omu-aran was the source of the raw fish bones (RFB), cow bones (RChB), and chicken bones (RCB). Additionally, the waste cooking oils (WCOs) from neighborhood eateries and groundnut cake fryers were waste groundnut oil (WGO) and waste sunflower oil (WSO). The rejected bone underwent a thorough water wash to remove any extraneous materials that had adhered to its surface, two rinses with distilled water, and a 24-hour drying period in a hot air oven set at 105°C. Using a pulverizer, the discarded bones were broken down into tiny particles. In a vacuum furnace, the pulverized waste materials were calcined at 600°C for two hours (Box-type resistance furnace). The heat treatment was employed to change carbonates and organic molecules into oxides [6]. The solid catalysts (CaO) were then kept in the dessicator.

2.2. CHARACTERIZATION OF NANO-CAO PARTICLES AND WASTE COOKING OILS

With the help of scanning electron microscopy (SEM), X-ray diffraction (XRD), X-ray fluorescence (XRF), Brunnar Emmet Teller (BET), and Fourier transform infrared spectroscopy (FTIR), the morphology, elemental components, crystalline phases, diffraction peak, and functional group of the solid alkaline (CaO) catalysts were identified. The chemical characterization and refinement, which included the acid value (mg/KOH/g), were done in accordance with AOAC's recommendations [7].

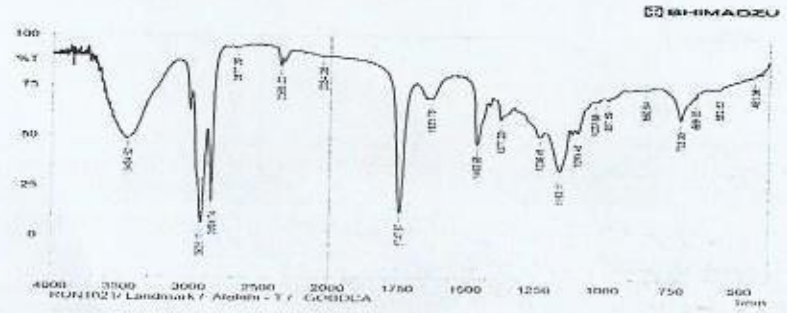
2.3 PROCESS OF TRANSESTERIFICATION

By first neutralizing the free fatty acid with an acid catalyst (esterification) and then transesterified with a base catalyst, the two refined cooking vegetable oils (RGO and RSO) underwent trans-esterification in two steps to produce a higher yield of ester. Trans-esterification at a predetermined molar ratio, reaction temperature, reaction duration, and reaction speed [8]

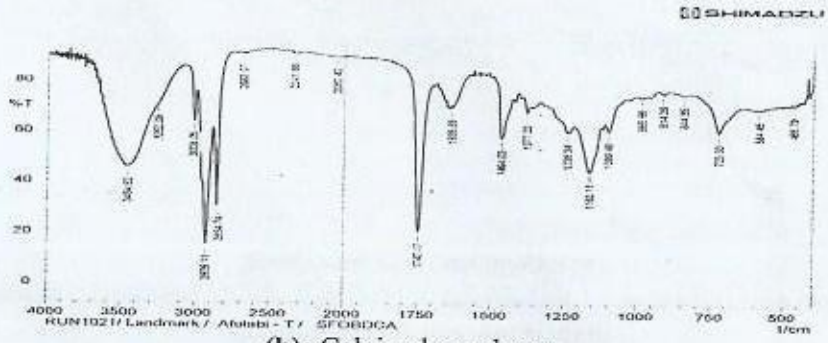
3.0 RESULTS AND DISCUSSION

3.1. CHARACTERIZATION OF n-CaO AND WASTE COOKING OILS

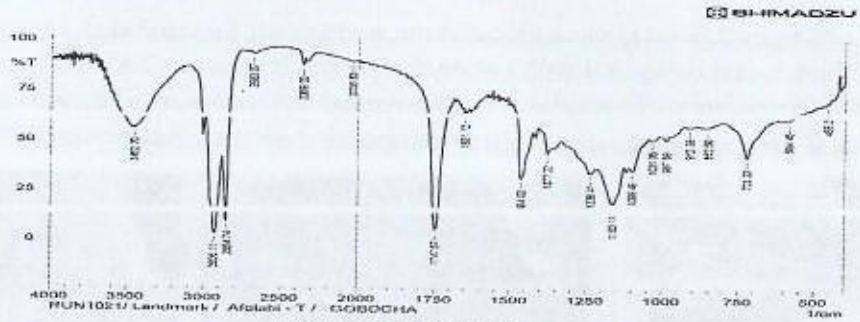
Table 1(b) showed calcined fish bone (CFB), chicken bone (CChB), and cow bone (RCB), whereas Figure 1(a) showed the FTIR spectra of raw fish bone (RFB), chicken bone (RChB), and cow bone (RCB) (CCB). All collagen-derived absorption bands, including those at 1545.45 cm-1 and 2800-3400 cm-1 bands, disappeared after calcination at 550–600°C, indicating that the organic component had been eliminated from the bone samples. Figure 1 (a-f bands) at 721.58 cm and 1464.90 cm (WFB), 712.40 cm and 1440.32 cm (WChB), and 602.7 cm and 871.261 cm (WCB), respectively, show the presence of out-of-plane bending, asymmetric stretching, and in-plane bending modes of the carbonate groups that were characteristic of natural dolomite. The vibration bands at 3495.35, 3412.86, and 3496.67 cm-1 corresponded to the IR bands of calcined bones in figure 1(g). Additionally, the waste bones' organic content at band 2925.95 cm-1 suggested the presence of an alkyl C-H stretch. Similar peaks from crab shell-derived CaO catalysts were seen [9].



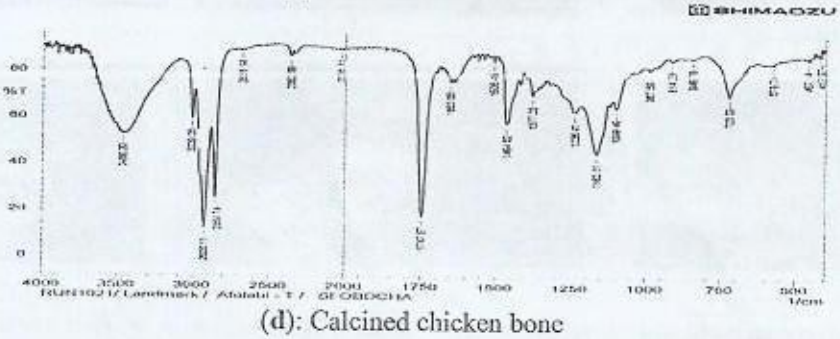
(a): Raw cow bone



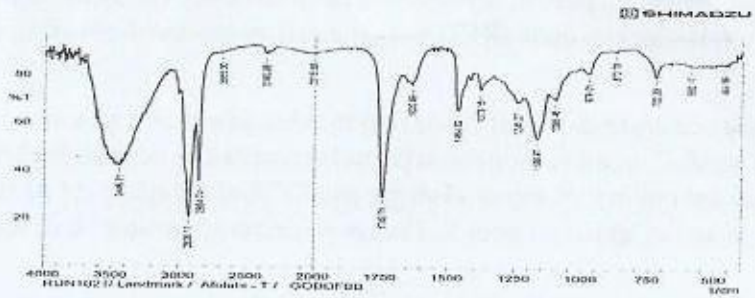
(b): Calcined cow bone



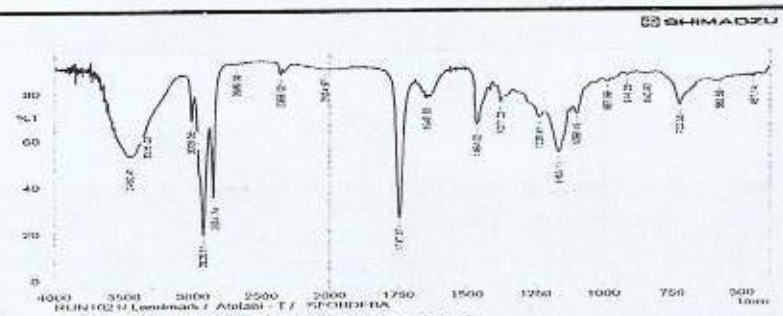
(c): Raw chicken bone



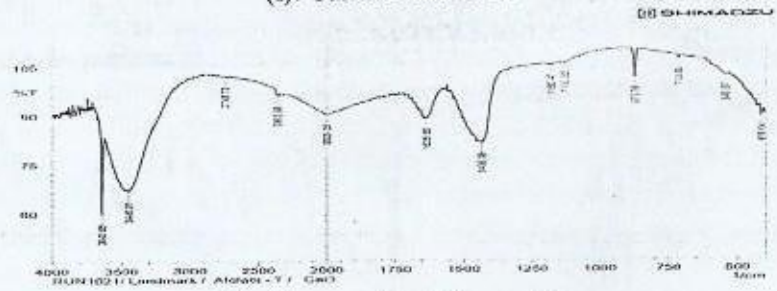
(d): Calcined chicken bone



(e): Raw fish bone



(f): Calcined fish bone



(g): Commercial calcium oxide

Figure 1: Bones of (a-b) cows, (c-d) chickens, (e-f) fish, and (g) commercial calcium oxide in their raw and calcined forms.

The morphology figures 2 (a - f) show the SEM micrographs of the natural and calcites of fish, cow, chicken bones, and compared with standard commercial calcium oxide. The micrograph displays show the structures of irregular and heterogeneous distribution of particle sizes of less surface area of $CaCO_3$ and organic matter), as compared to the calcined bones at 600 °C.



(a)



(b)



(c)



(d)



(e)



(f)

Figure 2: Analysis from scanning electron microscopy (SEM) (a) Raw fish bone (RFB), (b) calcined fish bone (CFB), (c) raw cow bone (RCB), and (d) calcined cow bone (e)raw chicken bone (RCHB) and (f) calcined chicken bone (CCHB).

The exothermic reactions that took place during the de-carbonation processes are presumably to blame for the smaller, more homogenous particles that can be seen in the SEM micrographs of the calcined animal bones. Figure 3 displays the TEM morphology of nano-CaO particles. It proves the particles' spherical nature. The range of detected particle sizes was 35 to 49 nm.

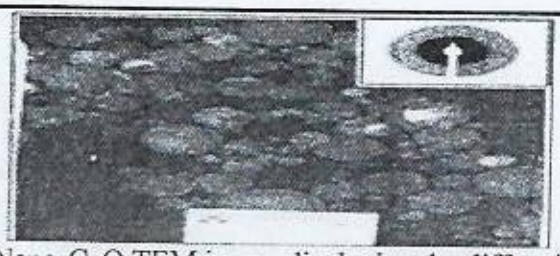


Figure 3: Nano-CaO TEM image displaying the diffraction pattern

The XRD spectra of the raw and calcined animal bones are shown in Figures 4(a) through (b). The conversion of aragonite (CaCO3) and chlorapatite (carbonated apatite) to calcium oxide that has been increased by thermal treatment at 600°C for 2 hours was used to reference the observed peaks using a standard Joint Committee on Powder Diffraction Standards file [10]. The carbonation and hydroxylation reactions that follow from direct exposure to ambient air produce the production of hydroxyapatite and other phases on the surface of calcined fish and chicken bones [11]. Peaks attributed to hydroxyapatite in calcined samples of catalyst produced from ostrich bones displayed a comparable pattern [12].

Calcite (animal bones) has an oxide composition of CaO (70.87, 64.19, and 70.20 % for CFB, CCB, and CChB, respectively), and it may be used as a biodiesel base catalyst because of its strong basicity, low toxicity, and straightforward water interactions (Joschek, 2016). The remaining 48.8 %was made up of minute amounts of other metal oxides (MgO, SiO, P2O5, Na_2O, Al_2O_3, K_2O, FeO, Cr_2O_3, TiO_2, Na_2O and SO_3). According to research, these oxides, which are active transesterification materials, increase the catalyst's fundamental strength [12–14].

3.2. CATALYST DOSAGE EFFECTS ON BIODIESEL PRODUCTION YIELDS

The effects of the catalyst dosage on the yields of refined groundnut oil-based biodiesel (RGOBD) and refined sunflower oil-based biodiesel (RSOBD) is shown in figure 5. The catalyst dosages for groundnut oil-based biodiesel at 1.0 wt. % of CaO produced 70, 86, and 85 % of CFB, CCB, and CCHB, respectively. The catalyst dosages for sunflower oil-based biodiesel at 1.0 wt. % of CaO produced 95, 70, and 60 % of CFB, CCB, and CChB, respectively. The production of sunflower biodiesel was 95% when 2.0 wt% CaO was used. For sunflower biodiesel, the 4.0 wt.% of CaO for CFB, CCB, and CChB generated 88, 95, and 86 %, respectively; for groundnut biodiesel, the 4.0 wt.% of CaO produced 75, 80, and 95 %; and for CFB and CCB, the 5 wt.% of CaO produced 75 and 80 %. The data and the findings were in agreement [13].

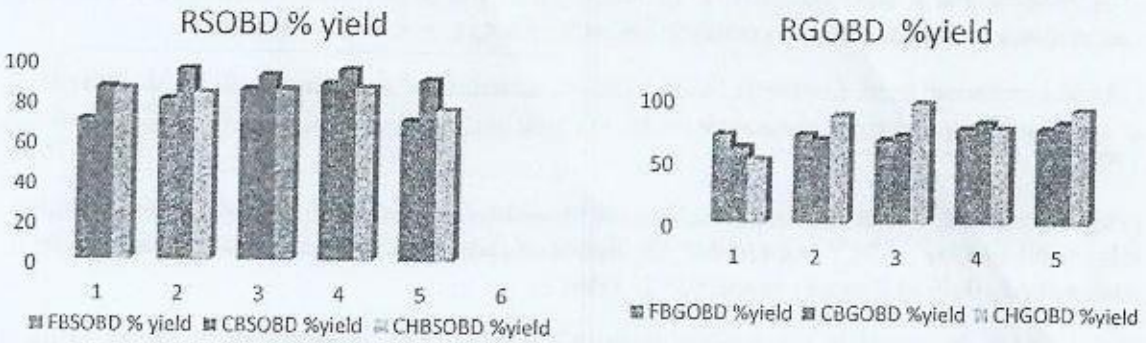


Figure 5: The yields of RSOBD and RGOBD as a function of catalyst dosage

CONCLUSIONS

After characterization, the use of waste cooking oils from sunflower and groundnuts and methanol as catalysts for the generation of biodiesel was examined to ascertain their catalytic effectiveness. The results showed that the optimum catalyst dose was 4 wt %, with better yields and specific gravity, density, kinematic viscosity, and acid values that are within the recommended standards of ASTM. The results were obtained by using various catalyst doses made from three animal bones and two used cooking oils. Because of its accessibility, low cost, poor solubility in methanol and ease of handling, the catalyst produces excellent results. The cost of producing biodiesel can be decreased by using calcium oxide made from calcined animal bones because it has relatively less negative environmental effects.

REFERENCES

[1] M.R.Abukhadra, M. Shaban, R. Hosny, A.M. Rabie, S.A. Ahmed, et al., (2019), Diatomite supported by CaO/MgOnanocomposite as heterogeneous catalyst for biodiesel production from waste cooking oil, J. Mol. Liquids, 279, 224-231, 2019.

[2] T. A. Degfie, T. T. Mamo and Y. S. Mekonnen (2019), Optimized Biodiesel Productionfrom Waste Cooking Oil (WCO) using Calcium Oxide (CaO)," Nanocatalyst, 9, 18982

[4] S. Kaewdaeng and R. Nirunsin (2019), Synthesis of Calcium Oxide from River Snail Shell as a Catalyst in Production of Biodiesel, Appl. Environ. Res, 41, 1: 31-37

[5] W. Widayat, T. Darmawan, and R.A. Rosyid RA (2017), Biodiesel production by using CaO catalyst and ultrasonic assisted, J. Phy. 877, 1-8

[6] L.M. Correia, N. De Sousa Campelo, and D.S. Novaes (2015), Characterization and application of dolomite as catalytic precursor for canola and sunflower oils for biodiesel production, Chem. Engr J, vol. 269, 35-43,

[7] AOAC (2012), Official methods of analysis, Association of official analytical chemist," 19th edition, Washington D.C., USA

[8] A.O. Mustapha, A. A. Adebisi, and B.O. Olanipekun, (2020), Characterization of Biodiesel from Alkaline Refinement of Waste Cooking Oil. Int. Annals of Sci, 10, 1:16-24

[9] D.S. Joshi, B.Y. Rawat, K.K. Lamba, P. Bisht, N. Kumar, D. Kumar and S. Kumar (2015), Energy Conv and Managt, 96, 258-267.

[10] A.Shah, and I. Rahman (2017), Enhanced biodiesel production from Jatropha oil using calcined waste animal bones as catalyst," Renew. Energy. vol. 101, p. 111-119

[11] M.L. Granados, M.Z. Poves, D. M. Alonso, R. Mariscal, F.C. Galisteo, R. Moreno-Tost, et al. (2007), Biodiesel from sunflower oil by using activated calcium oxide, Appl. Cat. B 73, 317-326

[12] M.A. Khan, M. Tariq, F. Ali, M. Ahmad, M. Ahmad, N. Zafar, et al. (2011), Identification, FT-IR, NMR (1H and 13C) and GC/MS studies of fatty acid methyl esters in biodiesel from rocket seed oil, Fuel Process Technol, 92, 336-341

[13] Q. Shu, B. Yang, H.Yuan, S.Qing, S and G. Zhu (2007), Synthesis of biodiesel from soybean oil and methanol catalyzed by zeolite beta modified with La3+, Cat. Comm. 8, 12, 2159-2165

[14] J.E. Asuquo, A.C. Anusiem, and E.E. Etim, (2010), Comparative study of the effect of temperature on the adsorption of metallic soaps of shea butter, castor and rubber seed oil ontohematie, Int. J. Mod Chem. 3, 39-50.

[15] A.B. Roger, R.A. Rebecca, A. Goerges, and I.O. Mathias (2016), Chemical characterizationof oil from germinated nuts of several coconut cultivars (cocosnuciferh L.)," Euro. J Sci. Res, 391, 514 – 522.