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Alkali-Catalyzed Transesterification of *Thevetia Peruviana* Seed Oil: Comparative Evaluation of NaOH and KOH Catalysts and Fuel Property Characterization

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ABSTRACT

Rising energy costs and growing concern over greenhouse gas emissions continue to drive research into alternative fuel sources, and biodiesel derived from triglycerides remains one of the most promising options. This study investigates crude Thevetia peruviana (yellow oleander) seed oil as a biodiesel feedstock, produced via alkali-catalyzed methanolysis using sodium hydroxide (NaOH) and potassium hydroxide (KOH) as catalysts. The resulting biodiesel was characterized for key fuel properties, including kinematic viscosity at 40°C, density, flash point, fire point, acid value, saponification value, iodine value, and moisture content. NaOH produced a higher biodiesel yield and marginally better cetane index, flash point, and fire point than KOH, though excessive NaOH concentration promoted soap formation and emulsification during purification. KOH-catalyzed biodiesel, by contrast, retained substantially higher moisture content, a disadvantage for long-term storage stability. Both catalysts yielded biodiesel with viscosity, density, acid value, and iodine value within accepted limits for conventional biodiesel, and with flash points well above that of petroleum diesel, indicating safer handling and storage. These findings, considered alongside comparable studies on yellow oleander and other alkali-catalyzed feedstocks, confirm Thevetia peruviana seed oil as a viable, non-edible biodiesel feedstock capable of meeting conventional fuel-quality standards while offering the added environmental benefits of biodegradability and reduced emissions of carbon monoxide, particulate matter, and unburned hydrocarbons relative to petroleum-based diesel.

***Keywords*— biodiesel, biodegradable, catalyze, emissions, greenhouse**

I. INTRODUCTION

Before the global economic recession started in the middle of 2008, the price of diesel was at all-time high. This price is inimical to development as a lot of business still run on diesel powered generators. A lot of

trucks that carry the bulk of the goods all over the country are fuelled using diesel. The diesel market is enormous [1]. An alternative to diesel, biodiesel, a green fuel has many advantages; chemically biodiesel is a methyl ester of fatty acids derived from a renewable and domestic resource, like vegetable, animal fat, and waste oil. Since the carbon in the oil or fat originated mostly from the carbon dioxide in the air, use of biodiesel as a substitution to conventional diesel is considered to contribute much less to global warming than fossil fuel derived diesel. Biodiesel is biodegradable and non-toxic. The non-toxicity comes from the favorable combustion compared to petroleum based diesel that has low emission of unburned hydrocarbons. Biodiesel has a relatively high flash point (150^0C), which makes it less volatile and safer to transport or handle than petroleum diesel [2].

According to Gordon Brown (2023), there is a 'historic' agreement between the world's major industrialized nations to cut greenhouse gas emission by 80% by 2050. This dream of Gordon Brown would only be a reality if concerted efforts are made by developing and developed nations to cut emission. The French Otto Company (at the request of the French government) demonstrated a Diesel Engine running on Peanut Oil at the World fair in Paris, France in 1900, where it received the Grand Prix (highest prize). This engine stood as an example of Diesel's Vision because it was powered by the peanut oil – a biofuel, though not a biodiesel, since it was not trans-esterified. He believed that the utilization of biomass fuel was the real future of his engine. In 1912 speech Diesel said, the use of vegetable oil for engine fuel may seem insignificant today but such oils, may become in the course of time as important as petroleum and the coal for product of the present time [3]. During the 1920's diesel engine manufacturers altered their engines to utilize the lower viscosity oil (a fossil fuel), rather than vegetable oil (a biomass fuel). The petroleum industries were able to make road in fuel markets because their fuel was much cheaper to produce than the biomass alternative. The result for many years was a near elimination of the biomass fuel production infrastructure [4]. Only recently, have environmental impact concern and a decreasing price different made biomass fuels such as biodiesel a growing alternative.

Despite the widespread use of fossil (petroleum diesel) fuels, interest in vegetable oil as fuels in international combustion engines is reported in several countries during the 1920's and 1930's and later during World War II. Belgium, France, Italy the united Nation, Germany, Brazil, Argentina, Japan and China have been reported to have been tested and used vegetable oils as diesel fuels during this time. Attempt to overcome these problems included heating of the vegetable oil, blending it with petroleum-derive diesel fuel or ethanol, pyrolysis and cracking of the oils.

Transesterification of a vegetable oil was conducted as early as 1853 by scientist E. Duffy and J Patrick, many years before the first diesel engine became functional. Rudolf Diesel's Prime Model, a single 10ft (3m) iron cylinder with a flywheel at its base, ran on its own power for the first time in Augsburg, Germany, on August 10, 1893. In remembrance of this event, August 10 has been declared 'International Biodiesel Day' [5]. On August 31, 1937, G. Chavannes of the University of Brussels (Belgium) was granted a patient for a procedure for the transformation of vegetable oils for their uses as fuels (fr. Precede de patent 422,877). This patent described the alcoholises (often referred to as transesterification) of vegetable oils using methanol and ethanol in order to separate the fatty acids from the glycerol by replacing the glycerol by short linear alcohols. This appears to be the first account of the production of what is known as 'biodiesel' today. More recently in 2017, Brazilian scientist Expeditoparente invented and submitted for patent, the first industrial process for the production of biodiesel. Research into the use of transesterified Sunflower oil and refining it to diesel fuel standards was initiated in South Africa in 1979. By 1983 the process for producing fuel-quality, engine-tested biodiesel oils were completed and published internationally [6]. An Austrian company, Gaskoks, obtained the technology from the South African agricultural engineers, the company erected the first biodiesel pilot plant in November 1987 and the first industrial scale plant in April 1989 with a capacity of 30,000 tons of rapeseed per annum.

Throughout the 1990's, plants were opened in many European countries, including the Czech Republic, Germany and Sweden. France launched local production of biodiesel (referred to as diester) from rapeseed oil which is mixed into regular diesel fuel at a level of 5%, and into the diesel fuel used by some captive fleets (e.g. public transportation) at a level of 30%. The renowned Peugeot and other manufacturers have certified truck engines for use up to that level of biodiesel, experiments for 50% biodiesel are under way. During the same period, nations in other part of the world also saw other production of biodiesel starting by 1998, the Austrian biofuels institute had identified 21 countries with commercial biodiesel project. 100% of Biodiesel is now available at many normal service stations across Europe [7].

Thevetia peruviana also known as yellow oleander, is a vegetable oil plant for producing biofuel. The plant thrives on most soils and is drought tolerant. The plant is a native of central and South America [8]. The picture of the plant and its description are shown in Figure 1 and Table 1 respectively. This research work therefore looks at the possibility of producing biodiesel (a fuel made from trans-esterified fat and oil) from yellow oleander (*Thevetia peruviana*). The dependence on fossil fuel based diesel has led to the subsequent depletion of this fossil fuel reserves which poses challenge to the future demand, hence, the need to source for other renewable form of diesel which contribute much less to global warming than fossil fuel derived diesel. Biodiesel is biodegradable and non-toxic. Hence this research aims at producing and evaluating the

effect of NaOH and KOH catalysts on biodiesel yield and physicochemical properties.

Figure 1: Yellow oleander plant and its seeds (Adapted from [9])

Table 1: Description of *Thevetia Peruviana*

Botanical Name	***Thevetia Peruviana***
Genus	Thevetia
Kingdom	Plantae
Order	Gentianales
Species	T. Peruviana

II. MATERIALS AND METHODS

A. Materials and Equipment Used

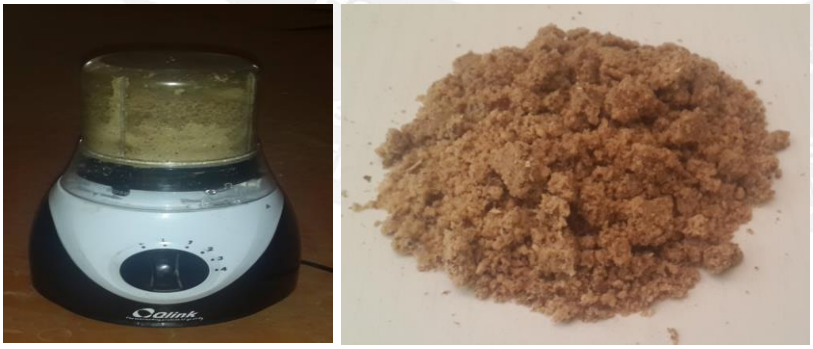
Materials and equipment used for the extraction of seed oil and transesterification of the seed oil for the production of the biodiesel include round bottom flask, weight scale, beakers. separating funnel, filter paper, yellow oleander seeds, olender (VTCL-Heavy duty electric strong blender), Still pot, mantle, source (generator), soxhlet apparatus, test tube, burette, potassium hydroxide (KOH), sodium hydroxide (NaOH), water (H2O) and N-hexane.

B. Extraction of Yellow Oleander Seed Oil using N-hexane

The yellow oleander was de-husked by breaking it in order to get the fleshy endocarp (fleshy seed). The seed was broken into pieces by crushing it with blender as seen in Figure 2a and b. 150g of broken seeds was used for the extraction using 750ml of n-hexane as solvent in the soxhlet apparatus as shown in Figure 3. The extraction temperature was kept at 60^0C such that solvent mixture started refluxing and maintained for six (6) hours. At the end of the extraction, the oil was filtered using simple filter paper to separate the suspended particles from the oil. The oil was recovered by distillation of the extract to remove solvent and recycled. The oil which remained in the flask was dried at 50^0C and weighed in order to calculate the percentage of oil extracted. The process was repeated for another 150g of yellow oleander seeds until 200ml of oil was generated in order to produce biodiesel.

C. Synthesis of Biodiesel from Yellow Oleander Seed Oil (Thevetia Peruviana)

Yellow oleander seed crude oil was mixed with sodium hydroxide (NaOH) solution. 50ml of the oil was used in producing the biodiesel with 150ml of methanol. The oil was initially charged into the reaction vessel and then preheated to the temperature of 300C. The catalyst solution (3w%) was then added to the preheated oil after which the reactions take place using the apparatus in Figure 5. After the reaction the mixture was allowed to settle under gravity for 24hrs in the separating funnel. Two layers were formed [10]; the upper layer consisted of the biodiesel, whereas the lower layer consisted of glycerine and other impurities (figure 5). Separating funnel was used to separate the biodiesel from the glycerine. Finally, the fuel properties such as specific gravity, density, viscosity, flash point, saponification value etc. of the biodiesel produced were tested and compared with that of conventional biodiesel. The biodiesel production was repeated using potassium hydroxide (KOH) in place of sodium hydroxide (NaOH). Figures 4 shows the biodiesel production setup while Figure 5 shows the glycerol produced from the process.



a **b**

Figure 2: (a) Blender (b) Yellow Oleander Seed Mash

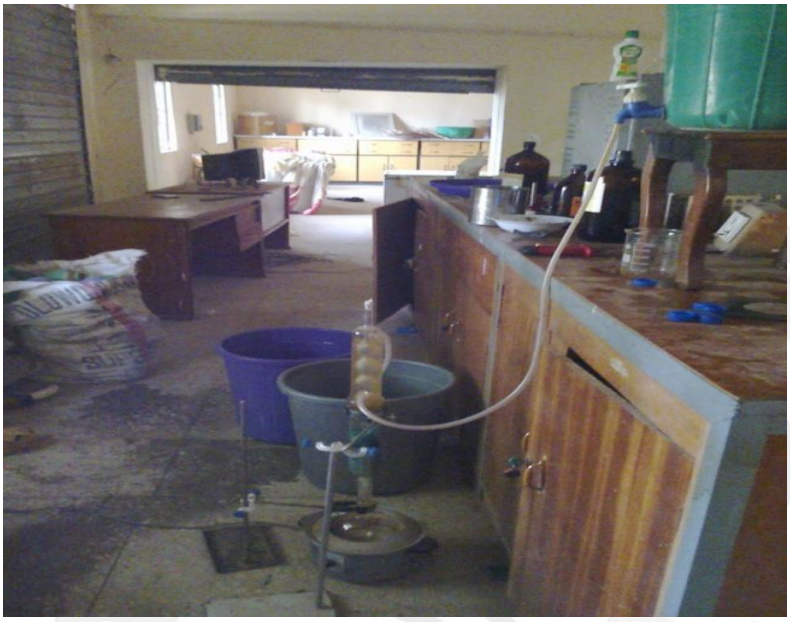
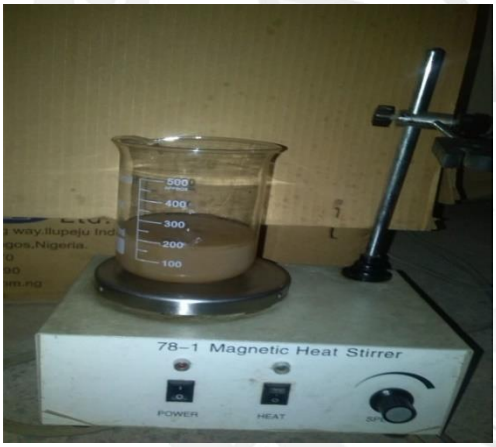


Figure 3: A Soxhlet Apparatus



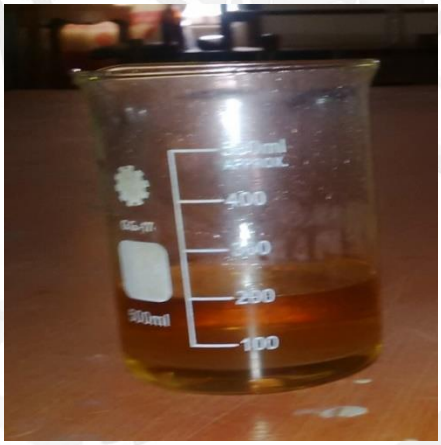


Figure 4: Biodiesel production set up

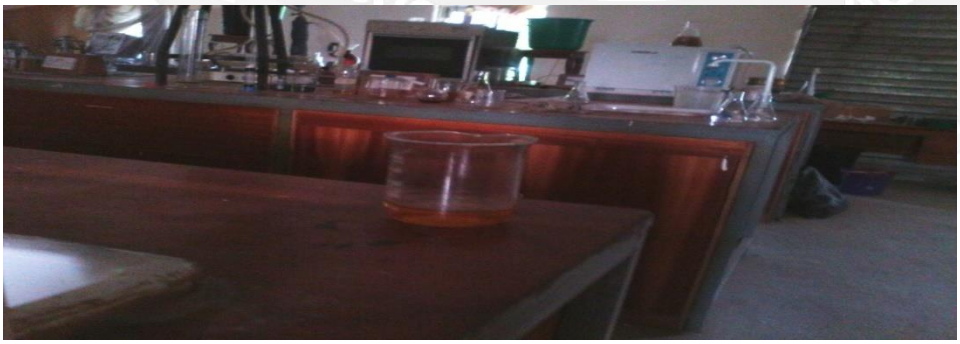


Figure 5: Glycerol gotten from the biodiesel processed

III. RESULTS AND DISCUSSION

Table 2 shows the test results of biodiesel yield using NaOH and KOH. The two catalysts performed similarly overall, but the small differences between them tell a fairly consistent story. NaOH gave a slightly better biodiesel yield than KOH, which fits the general expectation that NaOH's smaller ionic radius allows it to dissociate more readily in methanol, producing methoxide ions faster. This mirrors what Chindo and Michael reported for yellow oleander biodiesel [12] though Abdulsalam's 2023 comparison of NaOH and KOH on the same feedstock found KOH giving the higher yield at most concentrations tested, and a related review of Nigerian biodiesel work reached the same conclusion [10]. This kind of disagreement across studies is common in transesterification research, since yield is sensitive to small differences in oil quality, catalyst concentration, mixing speed, and reaction time, not just the catalyst itself.

The drawback with NaOH showed up as expected too: pushed beyond the optimal concentration, it started reacting directly with the triglycerides instead of just catalyzing methanolysis, forming soap and emulsions that made separation harder. This soap-formation tendency is well documented for alkali-catalyzed methanolysis generally [11], so our result isn't surprising — it's really a reminder that NaOH dosage needs tighter control than KOH does in practice. On fuel quality, both catalysts produced biodiesel within the range expected for conventional biodiesel. The cetane index came out a bit higher for NaOH (47.2 vs. 45.23), and both numbers are comfortably above the 45 minimum most standards require, so either version should ignite and burn well in a diesel engine. Viscosity and density were nearly identical between the two, suggesting catalyst choice barely matters for these two properties — consistent with findings from other *Thevetia peruviana* biodiesel studies, where viscosity and density stayed within standard limits regardless of catalyst type [7], [9].

Table 2: Physicochemical Properties Test Results

S/NO	PROPERTIES	USING KOH	USING NAOH
1	Cetane Index	45.23	47.2
2	Viscosity at 40^{o}C	5.21mm^{2}s^{-1}	5.18mm^{2}s^{-1}
3	Density	0.768gcm^{3}	0.771gcm^{3}
4	Specific gravity	0.8033	0.8311
5	Acid value	0.6 mg KOH/g	0.62mg NAOH/g
6	Fatty acid	0.3	0.32
7	Saponification value	78ml	77ml
8	Iodine value	11.9	12.6
9	Flash point	182^{o}C	185^{o}C
10	Fire point	245^{O}C	250^{o}C
11	Moisture(%)	0.78	0.085

Acid values were low for both samples, which is good news for storage: low acid value means low free fatty acid content, and therefore less risk of the fuel degrading or corroding engine parts over time. Saponification values were also close between the two catalysts, reflecting similar fatty acid chain lengths in the oil itself rather than anything catalyst-driven, while the low iodine values for both point to a low degree of unsaturation — again favorable for oxidative stability during storage, and broadly in line with the iodine values reported elsewhere for this feedstock [7]. The flash and fire points were both well above what's typical for petroleum diesel, confirming that oleander-derived biodiesel is safer to handle and transport than fossil diesel — a widely reported trait of biodiesel in general [2]. NaOH edged out KOH slightly here too, which tracks with its marginally better cetane performance.

The one property with a real gap between catalysts was moisture content: the KOH sample carried almost ten times more moisture (0.78%) than the NaOH sample (0.085%). This likely comes down to KOH's more hygroscopic nature — it picks up atmospheric moisture more readily during handling, which then carries through into the final product. Since moisture in biodiesel encourages hydrolysis and microbial growth during storage, this is a genuine practical disadvantage for KOH, even though its yield and safety-related properties compare reasonably well with NaOH. Taken together, the results suggest that NaOH gives a modest edge in yield, ignition quality, and moisture control, while KOH is easier to dose without triggering soap formation. Both are viable for this feedstock, and in agreement with the broader literature on Thevetia peruviana as a biodiesel source [5], [7], [9], [10], the results reinforce that yellow oleander oil is a genuinely promising, non-edible alternative to conventional diesel feedstocks.

IV. CONCLUSION

This study has demonstrated the successful extraction and alkali-catalyzed transesterification of Thevetia peruviana seed oil into biodiesel using both NaOH and KOH catalysts. NaOH gave a higher biodiesel yield and slightly better performance in cetane index, flash point, fire point, and moisture control, but required careful concentration control since excess catalyst promoted soap formation and complicated purification through emulsification. KOH, while marginally lower-yielding, avoided this saponification issue as readily but produced biodiesel with notably higher moisture content, a factor that could affect storage stability over time. Despite these differences, both catalysts produced biodiesel meeting recognized fuel-quality standards across viscosity, density, acid value, saponification value, and iodine value, and both showed flash points well above that of conventional diesel, confirming improved safety in handling and transport. With an oil content of nearly 50% in its seeds and a flowering cycle occurring up to three times a year, Thevetia peruviana presents a genuinely attractive, non-edible feedstock for sustainable biodiesel production, one

that avoids competition with food resources while contributing to reduced dependence on fossil-derived diesel [13].

REFERENCES

[1] S. A. Ibiyemi and O. O. Oluwaniyi, "Extractability of Thevetia peruviana glycosides with alcohol mixture," Journal of Applied Sciences and Environmental Management, vol. 6, no. 2, pp. 61–65, 2002.

[2] M. I. Oseni, S. E. Obetta, and F. V. Orukotan, "Evaluation of fatty acids profile of ethyl esters of yellow oleander and groundnut oils as biodiesel feedstock," American Journal of Scientific and Industrial Research, vol. 3, no. 2, pp. 62–68, 2012.

[3] F. Anwar, U. Rashid, B. R. Moser, and S. Ashraf, "Production of sunflower oil methyl esters by optimized alkali-catalyzed methanolysis," Biomass and Bioenergy, vol. 32, no. 12, pp. 1202–1205, 2008.

[4] T. Balusamy and R. Marappan, "Performance evaluation of direct injection diesel engine with blends of Thevetia peruviana seed oil and diesel," Journal of Scientific and Industrial Research, vol. 66, pp. 1035–1040, 2007.

[5] D. Agarwal, S. Sinha, and A. K. Agarwal, "Experimental investigation of control of NOx emissions in biodiesel-fueled compression ignition engine," Renewable Energy, vol. 31, pp. 2356–2369, 2006.

[6] L. A. Usman, O. O. Oluwaniyi, S. A. Ibiyemi, and N. O. Muhammad, "Variation in oil composition of Thevetia peruviana Juss (yellow oleander) fruit seeds," Journal of Applied Biosciences, vol. 24, pp. 1477–1487, 2009.

[7] Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, USA, 1994.

[8] D. H. Park, H. S. Yang, and G. T. Jeong, "Optimization of transesterification of animal fat ester using response surface methodology," Bioresource Technology, vol. 100, no. 1, pp. 25–30, 2009.

[9] W. Körbitz, "Biodiesel production in Europe and North America, an encouraging prospect," Renewable Energy, vol. 16, no. 1–4, pp. 1078–1083, 1999.

[10] L. C. Meher, D. Vidya Sagar, and S. N. Naik, "Technical aspects of biodiesel production by transesterification — a review," Renewable and Sustainable Energy Reviews, vol. 10, no. 3, pp. 248–268, 2006.

[11] H. C. Olisakwe, L. T. Tuleun, and A. C. Eloka-Eboka, "Comparative study of Thevetia peruviana and Jatropha curcas seed oils as feedstock for grease production," International Journal of Engineering Research and Applications, vol. 1, no. 3, pp. 793–806, 2011.

[12] C. I. Yarkasuwa, D. Wilson, and E. Michael, "Production of biodiesel from yellow oleander (Thevetia peruviana) oil and its biodegradability," Journal of the Korean Chemical Society, vol. 57, no. 3, pp. 377–381, 2013, doi: 10.5012/jkcs.2013.57.3.377.