Assessment of Biodiesel Yield from Varieties of Mango Seeds

Monday Ossai Edward[1*], Babatunde Saheed Bada[2], Adewale Matthew Taiwo[2], Ekundayo Temitope Ola[1], Olatunde Akindolie[1], Ibrahim Olajide Bazambo[1], Ojo Paul Adewoye[1], Abiodun Oladipo Ogundele[3].

[1]Bioresources Development Centre, National Biotechnology Development Agency,Ogbomosho, Nigeria.

[2]Department of Environmental Management and Toxicology, Federal University of Agriculture Abeokuta, Ogun State. Nigeria.

[3]Department of Biotechnology, National Centre for Genetic Resources and Biotechnology Ibadan, Nigeria.

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2025.12060003

Received: 20 May 2025; Accepted: 24 May 2025; Published: 26 June 2025

ABSTRACT

The rapid growth in global energy demand and carbon dioxide emissions from fossil fuels has driven the search for alternative, renewable energy sources with lower environmental impact. The search for alternative energy sources has become increasingly important to address social issues like rising petroleum prices and environmental concerns such as air pollution and global warming. Biodiesel is a biodegradable, renewable energy source with good lubrication properties and no sulfur or harmful aromatic compounds. This study assessed biodiesel production from Ogbomoso, Cherry and Saigon mango seeds. Cherry and Saigon mango seeds were sourced from National Horticultural Research Institute Ibadan and Ogbomoso mango seeds collected from Arada market in Ogbomoso town, Oyo State Oil extraction was through soxhlet apparatus and n-hexane as solvent. The data obtained were subjected to descriptive (mean and range) and inferential (ANOVA) statistics. Highest biodiesel yield was observed at 60 °C, 10 ml and 0.8 g of temperature, methanol and KOH respectively. Some of the fuel properties of biodiesel produced ranged between 125.91–169.31 mgKOH/g (saponification); 714.67– 892.33 g/cm^3 (density); 0.807–0.920 kg/l (specific gravity); 149.00–168.67 °C (flash point); 48.03–52.20 (cetane number); 4.32–6.80 mm^2/s (viscosity); 0.92–1.23 mgKOH/g (acid value); and 0.46–0.615 mgKOH/g (free fatty acid). These values were within the standard of American Society for Testing and Materials. Biodiesel produced from Cherry, Ogbomoso and Saigon of mango seeds had high flash point, largely methanol free and Ogbomoso mango produced more biodiesel among the mango seeds used during the study.

Keywords: Transesterification, Biodiesel, Bleaching agent, Mangifera indica and n-hexane.

INTRODUCTION

In recent decades, concerns have grown over the use of vegetable oils as a preferred material over petroleum or mineral oil due to environmental and sustainability issues. (1) The rapid growth in global energy demand and carbon dioxide emissions from fossil fuels has driven the search for alternative, renewable energy sources with lower environmental impact. (2,3) The search for alternative energy sources has become increasingly important to address social issues like rising petroleum prices and environmental concerns such as air pollution and global warming. (4,5) This has led to a widespread search for cheap and eco-friendly alternative energy sources. (6) A large number of studies on biodiesel production have been conducted due to its potential to reduce dependence on fossil-based liquid fuel (7). Biodiesel is defined as mono-alkyl esters derived from vegetable oils or animal fats by a chemical process called transesterification (8). Biodiesel is

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VI June 2025

biodegradable, renewable energy source with good lubrication properties and has no sulfur or harmful aromatic compounds. (9). Biodiesel production enjoys a positive social impact by enhancing rural revitalization. The use of biodiesel in diesel engine reduces CO and HC emissions and increases the NOx emission which is as a result of the increase in the level of Oxygen during combustion (10). According to Deeper et al. (11), transesterification is the process used in biodiesel production.

Technically, biodiesel is not yet considered a popular alternative source of energy to conventional fossil fuels worldwide due to its high production costs, which are largely attributed to the cost of raw materials and labor. As a result, the fundamental policy goals for biodiesel have not been fully achieved. The non-availability of raw materials and effective catalytic systems are major challenges facing the commercialization of biodiesel, hindering its ability to meet global demand and align with the United Nations Millennium Environmental goals (12).

According to reports (13, 14), mango (Mangifera indica) is considered a major fruit in Asia, with significant global production. India is regarded as the largest producer of mangoes, accounting for 44.4% of total world production.

According to Ayaga (15), Nigeria and Guinea are major mango producers in Africa. Mangoes are a nutrient-rich tropical fruit, renowned for their flavor and scent. They belong to the Family Anacardiaceae (16). They're rich in sugars, acids, polyphenols, and ascorbic acid, making them a valuable source of antioxidants. (17,18) Mangoes contain high levels of β-carotene and phytochemicals, which may help prevent various cancers. They're composed of three main parts: seed kernel, epicarp, and pulp. (19-23).

Mango kernels (seeds) require further processing beyond their use in canned fruit factories, as they contain a valuable fat called mango seed almond fat, which is rich in stearic acid, making them a potential resource for additional applications (24). It has been observed that mango peels and seeds are generated as waste during processing, accounting for approximately 40-50% of the total fruit weight (15). The kernel inside the seed represents 45-75% of the seed and about 20% of the whole fruit (25). The oil extracted from the kernel has a soft yellow color with a melting point of 32-36°C (26).

The oil is high in unsaturated fatty acids, such as oleic acid, which accounts for 46.2% (27). Global warming and unfavorable climate change are major concerns for users of fossil fuels. Rapeseed oil (28) and Desert Date seed oil (29) are considered sources of renewable energy and have been identified as suitable replacements for fossil fuels. Despite their abundance during harvest seasons, which often results in environmental waste, limited research has been conducted on producing biodiesel from mango seeds. This research gap motivated our study, which aimed to assess the potential of biodiesel production from three varieties of mango seeds.

MATERIALS AND METHODS

Collection and Preparation of Mango Seeds

Mango seeds, (Saigon and Cherry mango) were sourced Ibadan from National Horticultural Research Institute (NIHORT) while Ogbomoso mango was collected from Ogbomoso town both in Oyo state. These mango seeds were sun dried and cracked to collect the kernels which was also sun dried. The kernels were then grinded in a food grinder to reduce the particle size to a minimum diameter of 0.005 mm as measured by a sieve

Extraction of Oil from Mango seeds.

About 300 mL of normal hexane was poured into round bottom flask, while 100 g of the sample was placed in the thimble and was inserted in the center of the extractor. The Soxhlet was heated at 60°C and when the solvent was boiling, the vapor rise through the vertical tube into the condenser at the top. The liquid condensate dripped into the thimble in the Centre. The extract seeped through the pores of the thimble and filled the siphon tube, where it flowed downward into the round bottom flask. This process continued for a period of 6 – 8 hours. It was removed and oven dried, cooled in the desiccators and weighed to determine the amount of oil extracted (29) Further extraction was carried out repeatedly 3 times for better extraction (30) The extracted oil was stored in a container for subsequent characterization.

Experimental Design

The experimental design was 3 x 3 x 3 x 3 factorial (15) of mango seeds (Cherry, Ogbomoso and Saigon), temperature (45, 60 and 75 °C), methanol (5, 10 and 15 mL) and bleaching agent (KOH) (0.4, 0.8 and 1.2 g). The experiment was replicated thrice.

Acid Esterification Procedure

The extracted oil was dehydrated by heating to above 100 ^oC on a hot plate to remove its water content. The dehydrated oil was then esterified to reduce the percentage free fatty acid by agitating with a mixture of 300 ml methanol and 1 % (w/v) of H_2SO_4 acid, heated to 60 ^OC for one hour (31). The mixture was allowed to settle in a separating funnel, the upper layer containing methanol and water while the lower layer contained the vegetable oil. The oil was separated and methanol was recovered from methanol – water mixture.

Transesterification Procedure

25 mL of the oil was introduced into the reactor (thermometer and magnetic stirrer) and mounted on a hotplate, thereafter; measured amount of methanol/KOH stock solution (potassium methoxide.) 5 mL mixed for 10 minutes was added into the reactor and stirrer was put to start. The methoxide was introduced gently into the heated oil and entire content was brought to a temperature of 45^oC and maintained at this temperature for one hour reaction time. The temperature for the process was varied from 45 to 75^oC at a methanol volume of 5 to 15 mL, bleaching agent (KOH) weight of 0.4 to 1.2 g for one hour each. The reaction product mixture was then allowed to stand for 16 hours to separate into the biodiesel phase (upper phase) and glycerol (lower phase). The biodiesel produced was washed using warm water since water is a solvent that can dissolve KOH and methanol, and can also be separated from the oil after being mixed. The biodiesel layer was washed three times. and dried, then it was measured (using measuring cylinder) and recorded.

Data Analysis

Data collected were subjected to descriptive (mean, standard deviation and percentages) and Inferential (ANOVA) statistics. Means were separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effect of Temperature on Biodiesel Production from Seed oil of Cherry, Ogbomoso and Saigon mangos.

The effect of temperature on biodiesel production, as presented in Figure 3, shows that increasing the temperature from 45 to 60 °C increased the biodiesel yield of cherry mango from 58 to 71%. However, further increase in temperature resulted in a decrease in yield to 51%. Similarly, the yield from Ogbomoso mango seed oil increased from 61 to 72% as the temperature increased from 45 to 60 °C, but reduced to 52% when the temperature was adjusted to 75 °C. The yield from Saigon mango seed oil also increased from 63 to 69% as the temperature varied from 45 to 60 °C, but decreased to 51% with further temperature increase. There were significant ($p < 0.05$) differences in biodiesel yield among the three varieties at varying temperatures. The results indicate that the optimum temperature for biodiesel production from mango seed oil was 60 °C. Reaction temperature significantly impacts biodiesel production by influencing the reaction rate (32, 33). According to Umaru et al. (31), alkaline transesterification reactions are typically conducted near the boiling point of the alcohol used, and temperatures higher than this can burn off the alcohol, resulting in lower yields.

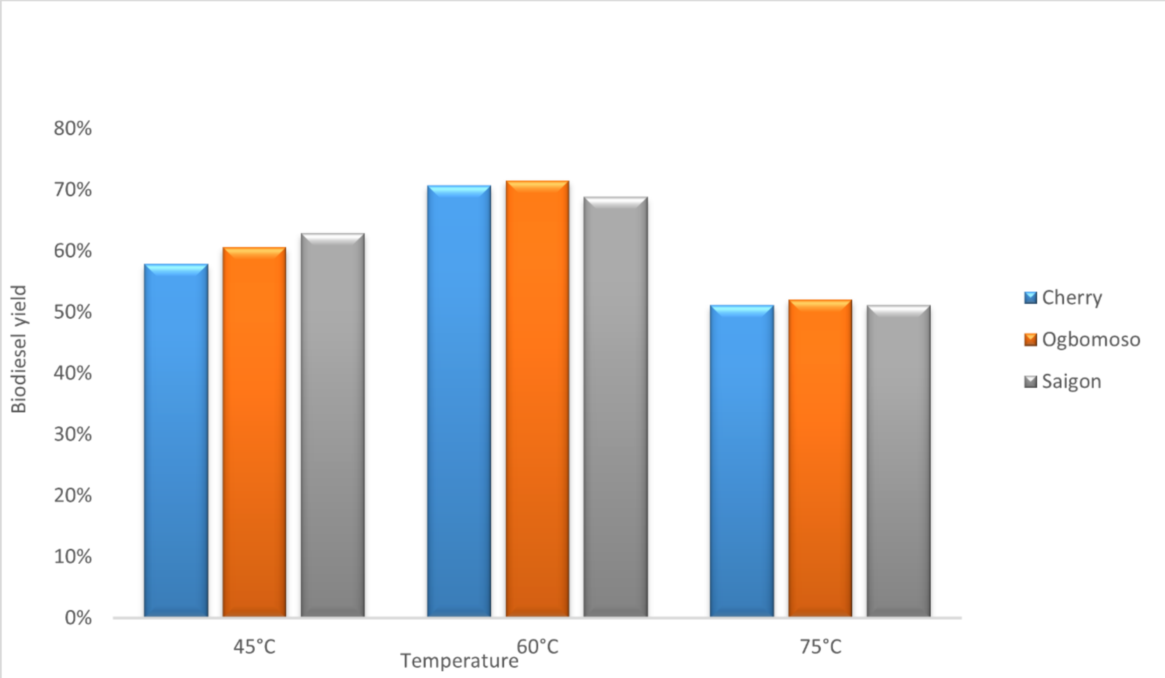

Figure 1: Effect of temperature on biodiesel production from mango seed oil, significant differences at $p < 0.05$ according to Duncan's Multiple Range Test.

Effect of Methanol on Biodiesel Production from Seed Oil of Cherry, Ogbomoso and Saigon mangos

Biodiesel yield produced from the mango pretreated oil increased as the methanol volume increased from 5 to 10 mL Further increase in methanol volume to 15 mL, resulted in decrease in the yield. On the contrary, the yield from Saigon mango oil decreased as the methanol volume increased from 5 to 15 mL as observed from Figure 2. The decrease in biodiesel yield when methanol volume increased to 15 mL suggests that the methanol content was high thereby resulting into more soap formation than the biodiesel causing difficulties in separating excess methanol from biodiesel and glycerol (34, 31). The yield at 15 mL volume of methanol differed significantly ($p < 0.05$) from the yields at 5 to 10 mL

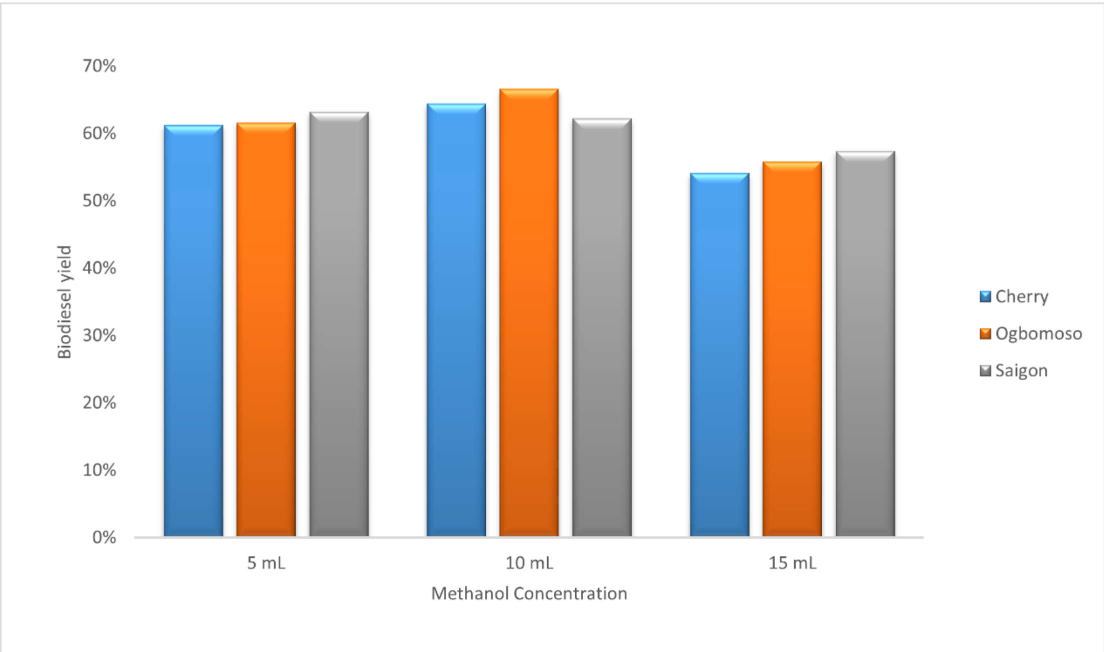

Figure 2: Effect of methanol on biodiesel production from mango seed oil, significant differences at $p < 0.05$ according to Duncan's Multiple Range Test.

Effect of Bleaching Agent (KOH) on Biodiesel Production from Seed Oil of Cherry, Ogbomoso and Saigon mangos

Increase Potassium hydroxide (KOH) from 0.4 to 0.8 g resulted in increased yield from 61 to 63 %. Upon further increase in KOH to 1.2g, the yield dropped to 56 %. Significant ($p < 0.05$) difference existed between the yield at 1.2 g and the yields at 0.4 and 0.8 g

The yield of biodiesel from Ogbomoso mango increased from 62 to 64 %, but reduced to 58 % as KOH varied from 0.8 to 1.2 g, significant ($p < 0.05$). In contrast to Cherry and Ogbomoso mangos, the yield from Saigon mango reduced significantly from 64 to 57 %, as KOH varied from 0.4 to 1.2 g. However, significant ($p < 0.05$) difference existed between the yield at 1.2 g and the yields at 0.4 and 0.8 g . The trend observed in this study showed that there was an increase in biodiesel yield as KOH increased from 0.4 to 0.8 g, but reduced at 1.2 g of KOH. This can be clearly explained by the reversible nature of transesterification reaction (31).

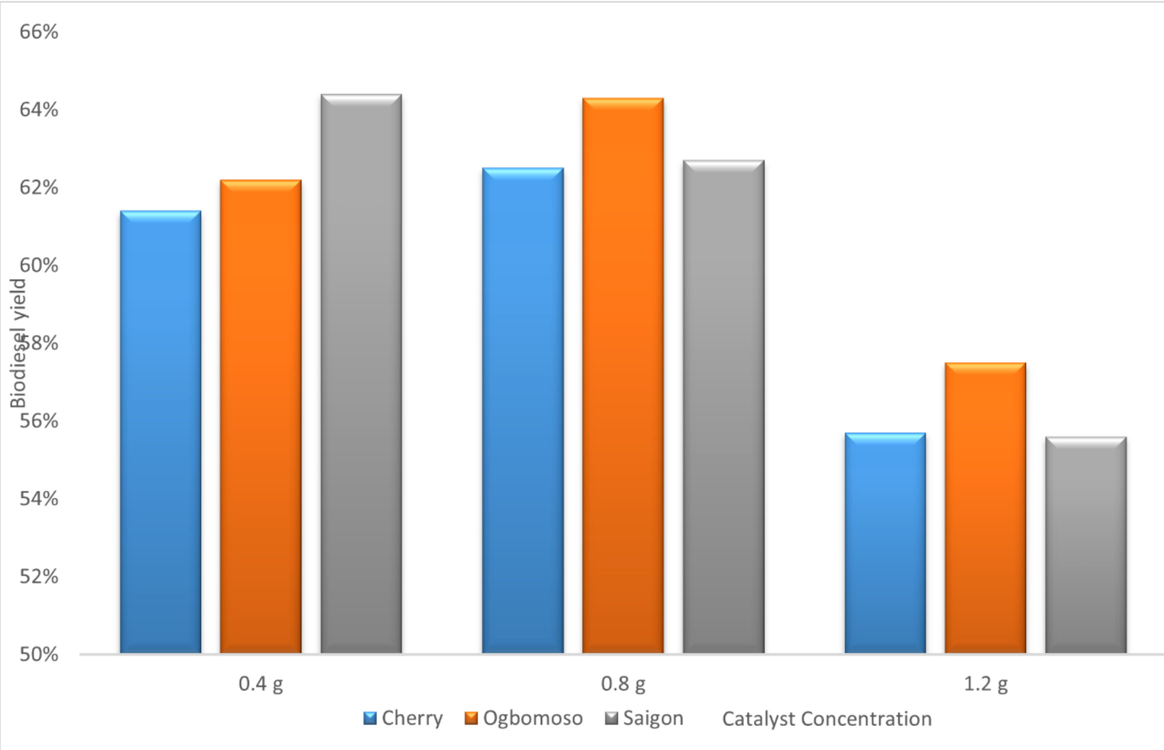

Figure 3: Effect of KOH on biodiesel production from mango seed oil

In comparing the biodiesel production from the three varieties of mangos (Table 1), Ogbomoso mango was higher than the Cherry and Saigon mangos. The results obtained from this study are similar to those of Baydir and Aras, (35). The study observed the optimum yield of 99 % at a temperature of 60 °C. The study conducted by Wang et al. (36) also reported an 80 % yield for palm oil.

Table 1: Comparison of yield from the three varieties of mango seeds (Cherry, Ogbomoso and Saigon).

Quantity	Temperature	Methanol quantity	Catalyst	Cherry	Ogbomoso	Saigon
25	45	5	0.4	0.609 ± 0.003^{c}	0.640 ± 0.004^{b}	0.669 ± 0.004^{a}
25	45	10	0.4	0.645 ± 0.015^{c}	0.679 ± 0.014^{b}	0.688 ± 0.004^{a}
25	45	15	0.4	0.509 ± 0.006^{c}	0.543 ± 0.020^{b}	0.676 ± 0.004^{a}
25	60	5	0.4	0.749 ± 0.001^{b}	0.685 ± 0.039^{c}	0.813 ± 0.004^{a}
25	60	10	0.4	0.820 ± 0.014^{b}	0.830 ± 0.013^{a}	0.754 ± 0.004^{c}
25	60	15	0.4	0.617 ± 0.004^{b}	0.631 ± 0.013^{a}	0.585 ± 0.004^{c}

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VI June 2025

25	75	5	0.4	0.524 ± 0.003^{c}	0.533 ± 0.002^{a}	0.533 ± 0.004^{a}
25	75	10	0.4	0.551 ± 0.011^{a}	0.542 ± 0.009^{b}	0.513 ± 0.004^{c}
25	75	15	0.4	0.506 ± 0.003^{c}	0.515 ± 0.002^{b}	0.569 ± 0.004^{a}
25	45	5	0.8	0.633 ± 0.001^{c}	0.651 ± 0.020^{jb}	0.656 ± 0.004^{a}
25	45	10	0.8	0.657 ± 0.004^{b}	0.681 ± 0.003^{a}	0.604 ± 0.004^{c}
25	45	15	0.8	0.537 ± 0.004^{c}	0.570 ± 0.002^{b}	0.658 ± 0.004^{a}
25	60	5	0.8	0.784 ± 0.015^{a}	0.749 ± 0.022^{b}	0.737 ± 0.004^{c}
25	60	10	0.8	0.858 ± 0.006^{b}	0.900 ± 0.007^{a}	0.838 ± 0.004^{c}
25	60	15	0.8	0.620 ± 0.004^{b}	0.643 ± 0.006^{a}	0.550 ± 0.004^{c}
25	75	5	0.8	0.508 ± 0.007^{c}	0.524 ± 0.004^{b}	0.534 ± 0.004^{a}
25	75	10	0.8	0.523 ± 0.006^{c}	0.551 ± 0.016^{a}	0.525 ± 0.004^{b}
25	75	15	0.8	0.510 ± 0.004^{c}	0.521 ± 0.003^{b}	0.547 ± 0.004^{a}
25	45	5	1.2	0.563 ± 0.012^{b}	0.576 ± 0.003^{a}	0.577 ± 0.004^{a}
25	45	10	1.2	0.547 ± 0.026^{c}	0.593 ± 0.013^{a}	0.555 ± 0.004^{b}
25	45	15	1.2	0.507 ± 0.003^{c}	0.519 ± 0.007^{b}	0.584 ± 0.004^{a}
25	60	5	1.2	0.633 ± 0.012^{c}	0.667 ± 0.020^{b}	0.675 ± 0.004^{a}
25	60	10	1.2	0.674 ± 0.008^{b}	0.720 ± 0.002^{a}	0.661 ± 0.004^{c}
25	60	15	1.2	0.612 ± 0.003^{a}	0.608 ± 0.007^{a}	0.578 ± 0.004^{b}
25	75	5	1.2	0.508 ± 0.003^{b}	0.519 ± 0.003^{a}	0.497 ± 0.004^{c}
25	75	10	1.2	0.520 ± 0.004^{a}	0.501 ± 0.003^{b}	0.458 ± 0.004^{c}
25	75	15	1.2	0.453 ± 0.016^{b}	0.473 ± 0.015^{a}	0.422 ± 0.004^{c}

Different superscripts in the same row indicate significant differences at $p < 0.05$ according to Duncan's Multiple Range Test

Fuel Properties of Biodiesel Produced from Three Varieties of Mango Seed Oil.

The physicochemical properties of biodiesel from Mangifera indica oil were evaluated, and the results are presented in Table 2. To determine the potential of the derived biodiesel as a substitute for petroleum diesel fuel, parameters such as density, specific gravity, kinematic viscosity, and flash point were assessed. The saponification values obtained (as shown in the table) were consistent with the standard specifications. The density of the produced biodiesel was found to be in agreement with the findings of Ayoola et al. (37) and the standard specifications mentioned in the table. The flash point values obtained for the biodiesel from all mango varieties met the ASTM (38) standard, as shown in Table 2. The high flash point values indicate that the biodiesel produced is largely free from methanol, which can reduce the flash point and affect diesel engine parts such as fuel pumps, seals, and elastomers (39). Additionally, the specific gravity of the biodiesel was found to be suitable and consistent with the ASTM (30) standard. The viscosity of the biodiesel met the ASTM (38) standard and was consistent with the findings of Darnoko (40). Overall, the results obtained from the biodiesel of Mangifera indica oil were mostly consistent with the standard specifications, as shown in Table 2.

Table 2: Fuel properties of biodiesel produced from three varieties of mango seed oil

Properties	Cherry	Ogbomoso	Saigon	ASTM standard
Saponification (mgKOH/g)	$125.91^{c} \pm 0.320$	$169.31^{a} \pm 0.552$	$146.14^{b} \pm 0.603$	-
Density (g/cm^3)	$772.67^{b} \pm 0.577$	$714.67^{c} \pm 1.155$	$892.33^{a} \pm 1.528$	860 – 900
Iodine value (meqiodine/g)	$58.80^{c} \pm 0.781$	$72.80^{a} \pm 0.361$	$60.97^{b} \pm 0.493$	-
Specific gravity (kg/l)	$0.836^{b} \pm 0.015$	$0.920^{a} \pm 0.010$	$0.807^{c} \pm 0.021$	0.88

Flash point (°C)	$152.00^{b} \pm 1.000$	$168.67^{a} \pm 0.577$	$149.00^{c} \pm 1.000$	100 – 170
Cetane number	$49.47^{b} \pm 0.153$	$52.20^{a} \pm 0.265$	$48.03^{c} \pm 0.503$	48 – 65 min
Viscosity (mm^2/s, @40°C)	$6.567^{b} \pm 0.058$	$4.32^{c} \pm 0.104$	$6.80^{a} \pm 0.100$	4.0 – 6.0
Acid value (mgKOH/g)	$1.07^{b} \pm 0.038$	$0.92^{c} \pm 0.020$	$1.23^{a} \pm 0.020$	0.5 max
Free fatty acid (mgKOH/g)	$0.535^{b} \pm 0.020$	$0.46^{c} \pm 0.010$	$0.615^{a} \pm 0.015$	-

Different superscripts in the same row indicate significant differences at $p < 0.05$ according to Duncan's Multiple Range Test.

CONCLUSION

The primary concerns associated with fossil fuel use are global warming and adverse climate change. Biodiesel is a promising alternative to fossil fuels due to its biodegradability, higher flash point, reduced exhaust emissions, and renewable energy source.

Although, the cost implication for producing one litre of this product (Biodiesel fuel) is of an increase when compared with cost of a litre of fossil fuel, this is stated below. Also, the availability of feedstock for the production of biodiesel is another factor which need to be considered because it will require large quantity of feedstock to produce large amount of the biodiesel. Moreso, the other challenges confronting the use of biodiesel is the modification of th engines for it use.

Utilizing mango seed oil for biodiesel production is a viable option, as mango seeds are abundant during harvest seasons and can help alleviate environmental waste.

Biodiesel derived from three varieties of mango seed oil meets standard fuel properties, making it a suitable alternative fuel source.

The optimal conditions for biodiesel production were found to be 60 °C, 10 mL of methanol, and 0.8 g of KOH, with Ogbomoso mango yielding the highest amount of biodiesel, followed by Cherry and Saigon mangos.

The study revealed that Ogbomoso mango seeds produced the highest yield of biodiesel compared to Cherry and Saigon mango seeds, making it a promising feedstock for biodiesel production.

Cost Analysis of Biodiesel Production (Conventional Method)

In the conventional biodiesel production process, approximately **1.287 litres of oil**, **0.515 litres of methanol**, and **41.18 grams of potassium hydroxide (KOH)** are required to yield **1 litre of biodiesel**.

Estimated Input Costs:

- **Methanol (0.515 L)** costs **₦1,648.00**
- **KOH (41.18 g)** costs **₦549.00**

Total Production Cost per Litre:

Combining the two gives a total cost of: ₦1,648.00 (methanol) + ₦549.00 (KOH) = ₦2,197.00

₦1,648.00 (methanol)+₦549.00 (KOH)=₦2,197.00

Therefore, the estimated cost to produce one litre of biodiesel using this method is ₦2,197.00, excluding the cost of raw oil and other operational expenses.

ACKNOWLEDGMENT

My appreciation goes to everyone for the success of this work and this start from the following people;

I appreciate Professor Babatunde Saheed Bada and Dr. Ademola Matthew Taiwo, the supervisory body for their support all through the period of this project work.

Appreciation also goes to Mrs. Titilola Tawakalit Falese and Mrs. Ekundayo Temitope Ola for their support in the contribution of the introductory part of the success of this work.

Mr. Olatunde Akindolie and Mr. Ibrahim Olajide. Bazambo are also recognized for their contribution on the review work of this research.

REFERENCES

1. Mohammed M, A,, Babagana, G, Bitrus,K ,H,and Shettima, A (2015) Soxhlet Extaction and Characterization of Oil from Canarium Schweinfurthii (Black Date)fruitsfor Domestic Purpose. Applied Research Journal 1(2):41 – 45.
2. Atabani, A. E, Silitonga, A. S and Ong, H .C.(2013). Non-edible vegetable oils: a critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. Renewable Sustainable Energy Revision, 18: 211–245.
3. Ho D. P, Ngo, H .H, and Guo, W.(2014). A mini review on renewable sources for biofuel. Bioresource Technology, 169: 742–749.
4. Darnoko D, Cheryan, M. and Perkins, E. G. (2000). Analysis of Vegetable Oil Transesterification Products by Gel Permeation Chromatography. Journal of Liquid Chromatography Relative Technology, 23(15):2327 – 2335
5. May, Y. K and Tinia, I. M, (2011). Ghazi, A review of biodiesel production from Jatropha curcas L. Oil. Renewable and Sustainable Energy Reviews 15: 2240 –2251
6. Benjamin P, Ugheoke, Kefas, H. M. and Onoche, E. O (2012). Determination of Optimal Catalyst Concentration for Maximum Biodiesel Yield from Tiger Nut Oil. Retrieved, 10 January 2013 from http://ijs.academidirect.org/A10/131136.htm ppl-5.
7. Hidaka J and Kouzu, M.(2011). Transesterification of Vegetable Oil into Biodiesel Catalyzed By Cao: A Review. Fuel , 93: 1–12
8. Rashid U, Rehman, H. A., Hussain, I., Ibrahim, M. and Haider, M. S. (2011). Muskmelon (Cucumis melo) Seed Oil: A Potential Non-Food Oil Source for Biodiesel Production. Energy 36: 5632–5639.
9. Keera, S. T., S. M. El Sabagh, and Taman A. R.(2018). Castor oil biodiesel production and optimization. Egyptian Journal of Petroleum, 27 (4):979–84.
10. Rakopoulos D.C and c Rakopoulos, (2011). eg grakopumis a mdimaratus , m a foulti, "comtarative environmental chavior of bus engine operating on blend of diesel fuel with four straight vegetable oil of greet origin sunflower, cottonseed, corn and olive " journal of fuel 90,. Pp. 3439 – 3446
11. Anton A. K, Alexandre, C. D. and Gadi, R. (2006) Solid Acid Catalyst for Biodiesel Production – Toward Sustainable Energy. Advance Synthesis Catalysis .. 348: 75 – 81.
12. Deeper V, Janmit, R, Amit, P and Manish,J.(2016). A critical review on production of biodiesel from various feedstocks.Journal of Scientific and Innovative Research, 5(2):51 - 58
13. Creed R, (2010). Relative Obesity: Variations of Antigolingrow. Winston-Salem Journal., 21: 83 – 89.
14. Kusuma D. K., Basavaraja, H. and Yatnati, K. J. (2014). Stability Analysis of Mango Export Markets of India: Markov Chain Approach, Agricultural. Science. Current Resource Nutrient Food Science Journal 2(3): 170 – 175.
15. Ayaga B (2007).Application of 23 Factorial Designs for Extraction and Characterization of Mango Kernel. B.Eng Degree Thesis, Department of Chemical Engineering, Federal University of Technology, Minna.

16. Lebaka VR, Wee YJ, Ye W, Korivi M.(2021). Nutritional Composition and Bioactive Compounds in Three Different Parts of Mango Fruit. International Journal of Environmental Research and Public Health. Jan; 18(2):741. doi: 10.3390/òerph18020741
17. Inbaraj BS and Sulochana N. Mercury adsorption on a carbon sorbent derived from fruit shell of Terminalia catappa. Journal of Hazardous Materials. 2006 May; 133(1-3):283-90. doi: 10.1016/j.jhazmat.2005.10.025
18. Phimnipha K,Adrian, F. and Sopart, S. (2009). Production of Cocoa Butter Equivalent from Mango Seed Almond Fat and Palm Oil Mid-Fraction. Asian Journal of Food and Agro-Industry 1 – 5.
19. Giri KV, Krishna Murthy DV, Narashimha Rao PL. (1953). Separation of organic acids. Journal of the Indian Institute of Science. 35:77-98.
20. Shang HS, Chen CJ, Shih YL, Peng SF, Chen YL, Liu KC, et al. (2020). Mangiferin induces immune responses and evaluates the survival rate in WEHI-3 cell generated mouse leukemia in vivo. Environmental Toxicology.Sep. doi: 10.1002/tox.23013
21. Baliga MS, Rao S, Rao P, Hegde SK, Akbar KC, Abraham S, et al.(2018). Use of Indian indigenous fruits in cancer prevention and treatment. InAnticancer Plants: Properties and Application (pp. 57-76). Springer, Singapore. doi: 10.1007/978-981-10-8548-2_3
22. Zeng Z, Lin C, Wang S, Wang P, Xu W, Ma W, et al. (2020). Suppressive activities of mangiferin on human epithelial ovarian cancer. Phytomedicine. 2020 Jun; 76:153267. doi: 10.1016/j.phymed..153267
23. Rajendran P, Rengarajan T, Nandakumar N, Divya H, Nishigaki I. (2015). Mangiferin in cancer chemoprevention and treatment: pharmacokinetics and molecular targets. Journal of Receptors and Signal Transduction Research. Feb; 35(1):76-84. doi: 10.3109/10799893.2014.931431
24. del Pilar Sánchez-Camargo A, Ballesteros-Vivas D, Buelvas-Puello LM, Martinez-Correa HA, Parada Alfonso F, Cifuentes A, et al.(2020). Microwave-assisted extraction of phenolic compounds with antioxidant and anti-proliferative activities from supercritical CO2 pre-extracted mango peel as valorization strategy. Lebensmittel-Wissenschaft and heTe c h n o l o g i e. 2 0 2 1 Fe b ; 1 3 7 :11 0 41 4 . d o i: 10.1016/j.lwt..110414
25. Kusuma, D. K., Basavaraja, H. and Yatnati, K. J. (2014). Stability Analysis of Mango Export Markets of India: Markov Chain Approach, Agricultural. Science. Current Resource Nutrient Food Science Journal 2(3): 170 – 175.
26. Kittiphoom,S, Sutasinee,S. 2013. Mango Seed Kernel Oil and its Physicochemical Properties. International Food Resource Journal 20(3):1145 – 1149.
27. Nzikou, J. M, Kimbonguila, A, Matos, L, Loumouamou, B., Pambou-Tobi, N. P. G, Ndangui, C. B, Abena, A. A, Silou, T. H, Scher, J. and Desobry, S. 2010. Extraction and Characteristics of Seed Kernel Oil from Mango (Mangifera indica). Research Journal of Environmental and Earth Sciences 2(1): 31 – 35.
28. Komers K, Stloukal, R., Machek, J. and Skopal, F.(2001). Biodiesel from Rapeseed Oil, Methanol and KOH. Analysis of Composition of Actual Mixture. European Journal of Lipid Science Technology, 103(6): 363 – 371.
29. Ogala H, Elinge, C . M, Wawata, I .G, Muhammed A.B and Ige A .R (2018). Oil Extraction and Biodiesel Production from Desert Date Seed via In-situ Transesterification using Cement Clinker as catalyst. International Journal of Applied Research and Technology 7(2): 35 – 41
30. Adebayo G.B, ,Ameen O.M and Abass L.T. (2011) Physico-chemical properties of biodiesel produced from Jatropha Curcas oil and fossil diesel. Journal of.Microbiol. Biotechnology Resource,. 1 (1): 12-16.
31. Umaru M, Mohammed, I. A, Sadiq, M. M, Aliyu, A. M, Suleiman, B. and Segun, T. (2014). Production and Characterization of Biodiesel from Nigerian Mango Seed Oil. Proceedings of the World Congress on Engineering. 1: 1 – 14.
32. Bajpai D, and Tyagi, V. K. (2006). Biodiesel: Source, Production, Composition, Properties and its Benefits. Journal of Oleo Science, 55(10): 487 – 502.
33. Devanesan, M. G, Viruthagir, T. and Sugumar, N.(2007). Transesterification of Jatropha Oil using Immobilized Pseudommas Fluorescens. African Journal of Biotechnology, 6(21): 2497 – 2501.

34. Gerhard G. J, ,Jurgen, K. and Van, K.(2005). Handbook of Biodiesel, AOCS Press Champaign Illinois, USA, 1 – 59.
35. Baydir E, and Aras, O. (2022). Increasing biodiesel production yield in narrow channel tubular reactors. Chem. Eng. Process. - Process Intensif., 170, 108719. doi:10. 1016/j.cep.2021.108719.
36. Wang X, Xu, X., Wang, Q., Huang, Z., He, J., and Qiu, T. (2020). Fatty acid methyl ester synthesis through transesterification of palm oil with methanol in micro channels :Flow pattern and reaction kinetics. Energy and Fuels 34(3),3628–3639.doi:10.1021/acs.energyfuels.9b03365
37. Ayoola A.A, Hymore, F.K, Obande, M.A, Udeh, I. N. (2012). Optimization of Experimental Conditions for Biodiesel Production. International Journal of Engineering Technology, 12:130 –133.
38. American Society for Testing and Materials (ASTM). (2008). Biodiesel Standard. United State of America Biodiesel National Board. American Journal of Applied Sciences 6(7): 1390 – 1395.
39. Wang Y. Z, Shemmeri, T, Eames, P, McMullan, J, Hewitt, N, and Huang, Y. (2006). An Experimental Investigation of the Performance and Gaseous Exhaust Emission of a Diesel Using Blends of a Vegetable Oil. Applied. Thermal. Engine. 26: 1684 – 1691.
40. Demirbas, A. (2005). Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods. Progress in Energy and Combustion Science, 31:466– 487.