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# Optimization of Transesterification Process for Biodiesel Production using Jatropha Oil

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## ABSTRACT

Biodiesel has attracted considerable attention during the past decade as a renewable, biodegradable, and non-toxic fuel alternative to fossil fuels. Biodiesel can be obtained from vegetable oils (both edible and non-edible) and from animal fat. Biodiesel was produced through esterification of Jatropha oil using an alkaline catalyst. The process was carried out at the reaction temperatures of 63 and 55°C, with a 6:1-11:1 oil to methanol molar ratio, and the concentration was verified. In this research work, a yield of 91.78% and 80% was achieved. Furthermore, the flash point of 129.1°C obtained indicates that the biodiesel is within the specification of ASTM. *Jatropha curcas Linnaeus*, a multipurpose plant, contains a high amount of oil in its seeds which can be converted to biodiesel. *J. curcas* is probably the most highly promoted oilseed crop at present in the world. The availability and sustainability of sufficient supplies of less expensive feedstock in the form of vegetable oils, particularly *J. curcas*, and efficient processing technology to biodiesel will be crucial determinants of delivering competitive biodiesel. Oil contents, physicochemical properties, and fatty acid composition of *J. curcas* are reported in research. The fuel properties of Jatropha biodiesel are comparable to those of fossil diesel and conform to the ASTM standard. The objective of this review is to give an update on the *J. curcas L.* plant, the production of biodiesel from the seed oil, and research attempts to improve the technology of converting vegetable oil to biodiesel and the fuel properties of Jatropha biodiesel. There is also a need to carry out a life-cycle assessment and assess the environmental impacts of introducing large-scale plantations. Furthermore, there is still a dearth of research about the influence of various cultivation-related factors and their interactions and influence on seed yield. The formation of biodiesel was confirmed by FT-IR and GC-MS analysis, and the conversion of ester functional group into methyl esters was verified, and characteristic properties of biodiesel were successfully determined.

**Keywords:** Biodiesel, Jatropha oil, transesterification, catalyst, optimization, renewable energy and sustainability

## INTRODUCTION

Biodiesel, derived from renewable sources such as vegetable oils or animal fats, is an eco-friendly alternative to fossil fuels. It offers benefits including reduced greenhouse gas emissions and improved air quality [1]. *Jatropha curcas*, a non-edible plant with high oil content, has emerged as a promising feedstock for biodiesel production due to its ability to grow on marginal lands. The importance of biodiesel lies in its ability to address multiple challenges associated with fossil fuels. Firstly, biodiesel serves as a cleaner-burning fuel, emitting lower levels of particulate matter and pollutants compared to conventional diesel [2]. This characteristic is crucial in mitigating air pollution and enhancing public health, particularly in urban areas where traffic-related emissions are a significant concern [3]. Secondly, biodiesel is a viable strategy for reducing dependence on finite fossil fuel resources. As an alternative energy source, biodiesel contributes to diversifying the energy mix, promoting energy security, and mitigating the environmental impacts of fossil fuel extraction and combustion [4]. Furthermore, biodiesel can play a role in addressing global climate change. The carbon dioxide released during the combustion of biodiesel is offset by the carbon dioxide absorbed by the plants during their growth, making biodiesel a carbon-neutral or low-carbon alternative [5].
Biodiesel production involves various methods, with transesterification and esterification being the prominent approaches. Transesterification is a well-established method in biodiesel production, involving the reaction of triglycerides with alcohol, typically methanol or ethanol, in the presence of a catalyst [6]. This process results in the formation of fatty acid methyl esters (FAMEs), the primary constituents of biodiesel. Esterification, another route for biodiesel synthesis, involves the reaction of triglycerides with alcohol in the presence of an

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acid or alkaline catalyst [7]. This process is particularly suitable for feedstocks with high free fatty acid (FFA) content, offering an alternative to transesterification. Recent advancements in biodiesel production methods include the exploration of novel catalysts and process integration strategies. For instance, heterogeneous catalysts, such as solid acid or base catalysts, have gained attention for their potential to simplify biodiesel production and reduce environmental impact [8]. Additionally, enzyme-catalyzed transesterification has emerged as a green and efficient method, addressing some of the drawbacks associated with traditional homogeneous catalysts [8]. Jatropha (*Jatropha curcas L.)* is a drought-resistant, perennial plant that has garnered significant attention as a potential feedstock for biodiesel production due to its high oil content and adaptability to marginal lands [9]. In recent years, extensive research has been conducted to evaluate the agronomic, biochemical, and economic aspects of Jatropha cultivation and its potential as a bioenergy crop. The aim of this study was to investigate and optimize the transesterification process for biodiesel production using Jatropha oil, with a focus on enhancing efficiency, sustainability, and economic viability,



## MATERIALS AND METHODS

### Equipment and Apparatus

Round-bottom flasks for reaction vessels, Magnetic stirrers to ensure proper mixing during the reaction, Condensers to collect and condense any volatile substances, Separatory funnels for phase separation in the biodiesel purification process and Rotary evaporator for solvent removal (if applicable) [10].

### Study Area

The study area was set at Watsilla village in Michika Local Government Area of Adamawa State, the village lies between latitudes 10°32'15"N and longitudes 13°19'49"E, spanning approximately 4.5km, covering a land area of about 142,199 km2.

### Study Design

The study was utilize an experimental research design to optimize the transesterification process using Jatropha oil for biodiesel production sourced from Michika Local Government Area, Adamawa State, Nigeria. The experimental approach was entail the systematic manipulation of key variables to evaluate their influence on the efficiency and yield of biodiesel production. Independent variables to be considered include reaction temperature, reaction time, catalyst concentration, and alcohol-to-oil molar ratio. Dependent variables encompass biodiesel yield, reaction efficiency, and quality parameters such as viscosity and density.

### Collection and Identification of Plant Materials

The research focused on plants with historical usage in native remedies. The plants was gathered from Watsilla Michika Local Government in Nigeria and authenticated at the State University of Mubi, Adamawa State Botanical Department Herbarium.

### Analytical Studies of the Samples

### Thin layer chromatography (TLC)

Semi-quantitative analysis of biodiesel was carried out using TLC method. Silica gel-G coated on glass plate was activated for overnight at 60 °C and 0.5 µl of samples was applied. For biodiesel analysis, the solvent mixture of n-hexane:ethylacetate:acetic acid (94:5:1, v/v/v) will be used as mobile phase. After chromatographic development (~30 min), plate was allow to air dry at room temperature (i.e., 30 °C) for half an hour. Follow by saturation with iodine chamber (5–10 min) and spots were recorded [11].

### Gas Chromatography – Mass Spectrometry (GC-MS)

Jatropha oil was analyzed by a GC-MS instrument: Thermo-Finnigan Trace DSQ, that contains a Hewlett-Packard-5 (crosslinked 5%-phenyl-methyl-polysiloxane) column with dimensions of 30 m x 0.32 mm and a 0.25 µm film thickness. The auto-injector was operated in the splitless mode at 220°C, helium was used as a carrier gas at a flow rate of 1.5 mL/min. 1 µL of sample was injected using a Thermo Scientific TriPlis RSH autoinjector, the oven temperature was hold 80°C hold for 1 min and then it was increased to 200°C, at a rate of 10°C/min. Followed by an increase to 270°C at 8°C/min and hold at that temperature for 1 min [12].

### Fourier Transform Infrared Spectroscopy (FTIR)

Free fatty acids in the sample was determined and fourier transform infra-red spectrometer (Nicolet 5700) was used to determine some of the functional groups present and was compared with European EN 14103:2003. The ME yield was calculated [13].

## RESULTS AND DISCUSSION

**Table 1: Catalysts utilized as basic solids for transesterification reaction.**

| Catalyst | Feedstock | Temp. | Time | Methanol/Oil | Catalyst amount | Biodesel yield |
|---|---|---|---|---|---|---|
| alkaline | Jatropha oil | 55°C | 60min | 6:1 | 0.2 wt% | 68.7% |
| alkaline | Jatropha oil | 63°C | 60min | 11:1 | 1.5 wt% | 78.5% |

A 68.7% biodiesel yield was achieved from the transesterification of Jatropha oil using 0.2 wt% catalysts, maintaining a 6:1 methanol-to-oil ratio for a 60-minute reaction time at 55°C. Additionally, a separate reaction with 6 wt% catalysts, utilizing an 11:1 methanol-to-oil ratio, sustained for 60 minutes at 63°C, yielded a superior 78.5% biodiesel. The results indicate that catalyst concentration, methanol-to-oil ratio, and reaction temperature significantly influence the biodiesel yield from Jatropha oil. The higher catalyst concentration and methanol-to-oil ratio in combination with an elevated reaction temperature resulted in the highest yield of 78.5%. The results are in accordance with the findings of similar studies, underscoring the importance of optimizing these parameters to achieve efficient biodiesel production. The yield of the biodiesel obtained from the Jatropha oil was calculated using the equation below.

Biodiesel yield (%) = (Weight of biodiesel / Weight of oil sample used) × 100

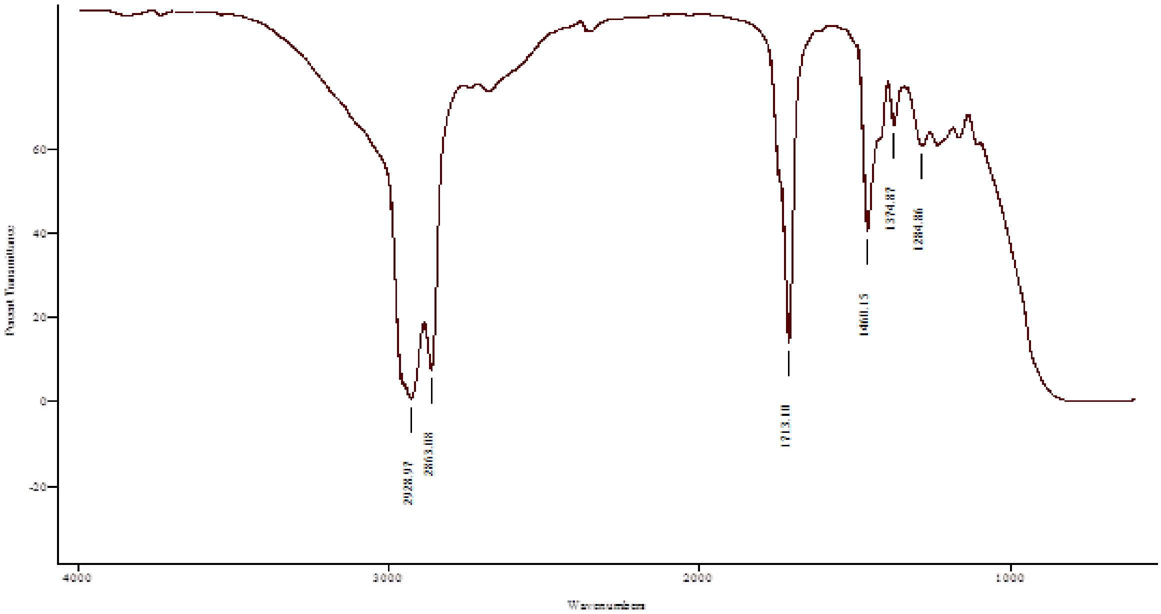


**Figure: 1 Results of Jatropha oil biodiesel**

**Table 2a: Jatropha oil Biodiesel**

| Filename | Peak At | Peak Height |
|---|---|---|
| Jatropha Biodiesel | 1284.86 | 60.64 |
| Jatropha Biodiesel | 1374.87 | 65.72 |
| Jatropha Biodiesel | 1460.15 | 40.53 |
| Jatropha Biodiesel | 1713.10 | 13.84 |
| Jatropha Biodiesel | 2863.08 | 7.54 |
| Jatropha Biodiesel | 2928.97 | 0.71 |

These results suggest that the Jatropha oil biodiesel contains multiple compounds, each absorbing light at different wavelengths. The peak heights indicate the relative concentrations of these compounds in the biodiesel. The presence of peaks at specific wavelengths can be used for identification and characterization of the compounds present in the biodiesel samples. The differences in peak positions and heights between the samples indicate variations in their chemical composition or concentration of certain compounds.

**Table 2b: FTIR of Jatropha oil of biodiesel produce**

| Peak value cm-1 | Functional group | Type of vibration | Characteristic absorption cm-1 | Intensity |
|---|---|---|---|---|
| 1284.86 | C-H | Stretch | 2850-3000 | Strong |
| 1374.87 | C-H | Stretch | 2850-3000 | Strong |
| 1460.15 | C=C | Stretch | 1400-1600 | Medium –weak multiple bands |
| 1713.10 | C=O | Stretch | 1700-1725 | Strong |
| 2863.08 | C-O | Stretch | 1000-1300 | Two bands or more |

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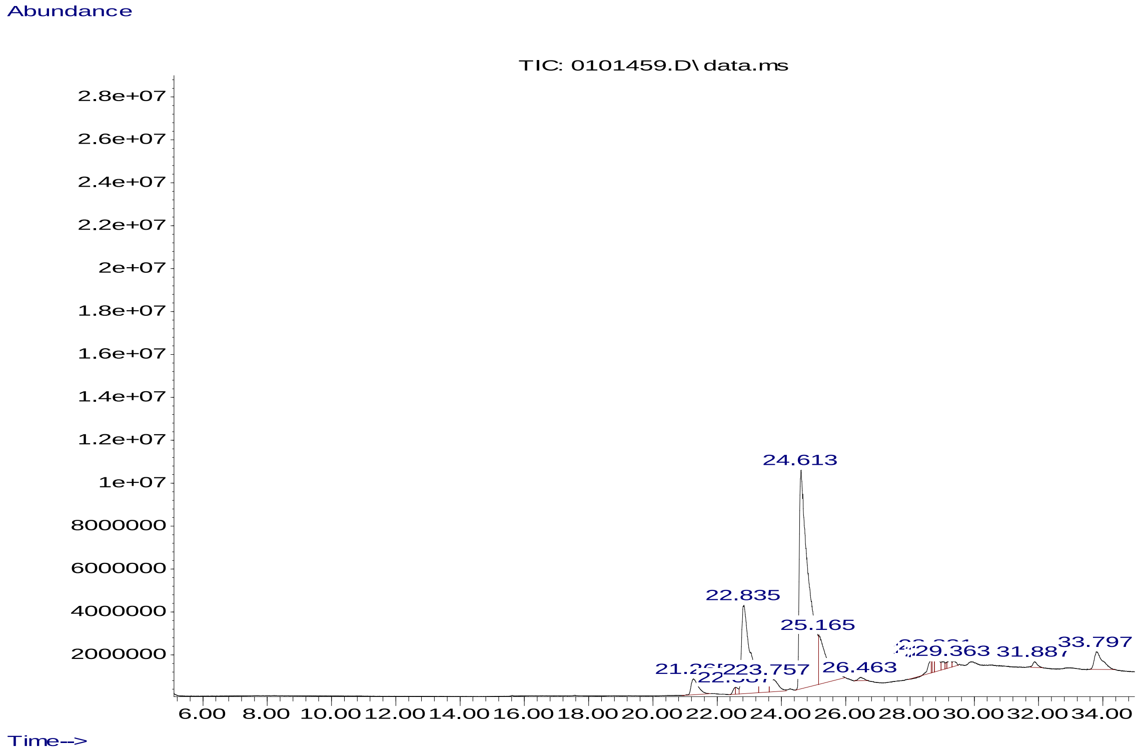


**Figure 2: Mass Spectra of Jatropha oil of biodiesel**

**Table 3: Results of the GC-MS analysis of Jatropha oil Biodiesel**

| Retention time | Area % | Molecular weight g/mol | Compound name | Molecular formular |
|---|---|---|---|---|
| 21.264 | 2.87 | 270.4507 | Hexadecanoic acid, methyl ester | $C_{17}H_{34}O_2$ |
| 22.834 | 18.54 | 280.445 | 10,13-Octadecadienoic acid, methyl ester | $C_{18}H_{32}O_2$ |
| 23.375 | 2.38 | 280.4472 | 9,12-Octadecadienoic acid, methyl ester | $C_{18}H_{32}O_2$ |
| | | | | |
| 24.612 | 51.70 | 280.4472 | 9-Octadecenoic acid, methyl ester | $C_{18}H_{32}O_2$ |
| | | | | |

**Table 4: Properties of biodiesel produced from Jatropha oil**

| S/N | properties | ASTMD-677-02 | Jatropha Oil |
|---|---|---|---|
| 1 | Viscosity @ 40 $^0$C mm/s$^2$ | 1.9-6 | 4.45 |
| 2 | Density (g/cm3) | - | 0.777 |
| 3 | Moisture | | 0.11% |
| 4 | Specific gravity | | 0.8862 |
| 5 | Flash point | 130 | 129.1$^o$C |
| 6 | Cloud point | -15 - 12 | 10.1$^0$C |
| 7 | Pour point | (-15) – 16 | 12.1$^o$C |

Viscosity =
V=Ct.
Where C is viscometer constant 2.818
T =Time of flight in seconds 1.58

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## DISCUSSION

The oil yield of 91.18% was obtained after the chemical extraction process, with an average of 0.11% accounting for the moisture content (Table 1). This small moisture content was largely due to the condition of the seeds at the time of harvesting. **Table 2:** FTIR analysis is important to confirm the functional groups that are present in the Jatropha oil biodiesel. Figure 4 shows an overlay of FTIR spectra of Jatropha oil biodiesel. The absorption bands observed at 1284.86 and 1374.87 $cm^{-1}$ can be related to stretches of C-H (alkanes), and sharp bands at 1713.10 $cm^{-1}$ can be assigned to C=O stretches (ketones, carboxylic acids, and esters) [14]. The absorption bands observed at 2863.08 $cm^{-1}$ can be ascribed to C-O stretches (ester). The peaks at 721 and 720 $cm^{-1}$ can be related to C-H bending vibration (long-chain fatty acids) [15]. Overall, results obtained from FTIR analysis confirmed the formation of fatty acid methyl esters (FAMEs) in Jatropha oil biodiesel. **Table 3:** In this study, the fatty acid composition of Jatropha biodiesel was analyzed using GC-MS. In general, GC-MS was mainly applied for determining the degree of saturation and unsaturation of biodiesel. Figure 2 displays the GC-MS chromatogram of the Jatropha biodiesel produced from Jatropha oil. As can be seen from Figure 2, four FAMEs were detected in the Jatropha oil, including hexadecanoic acid, 10,13-octadecadienoic acid, 9,12-octadecadienoic acid (Z,Z)-, and 9-octadecenoic acid. It is evident from GC-MS analysis that Jatropha oil biodiesel comprises saturated and unsaturated FAMEs. **Table 4:** The density of Jatropha oil was measured and calculated as 0.777 $kg/m^3$. The importance of the density of a diesel fuel can never be overemphasized as it gives an indication of the delay between the injection and the combustion of the fuel in a diesel engine (ignition quality) and the energy per unit mass [16]. It was observed that the viscosity (4.45) of Jatropha oil methyl ester was within the limit (1.9-6 $mm/s^2$) specified by the American Society for Testing and Materials standards (2003). The biodiesel produced has a viscosity within the value stipulated by ASTM D445 and D874, 2007. One of the most important characteristics of any fuel is its flash point. The flash point of Jatropha oil was determined via flash point tester and it was found to be above 90 °C. This makes the biodiesel sample safe for use and storage [8]. The pour point is the lowest temperature at which the oil/fuel can flow. This property is related to the use of biodiesel in colder regions [17]. Jatropha oil biodiesel has a pour point of 12.1 °C.

## CONCLUSION

Conscious efforts at pursuing the renewable energy program through the unveiling and popularizing the use of biodiesel from Jatropha oil is viable. This undoubtedly will save the world from impending economic embarrassment that may throw it into an avoidable energy crisis, in addition to protecting the universe by going green. Results have shown that the properties of biodiesel from Jatropha oil are such that it can be used in already existing diesel engines, not forgetting the fact that absolute use of biodiesel as fuel in such engines can be employed without necessarily acquiring new systems. The optimized transesterification process for Jatropha oil demonstrated improved biodiesel yield and quality. This study underscores the potential of Jatropha oil as a sustainable feedstock, contributing to renewable energy solutions and environmental sustainability.

## REFERENCES


1. Smith, A., & Johnson, B. (2022). The Environmental Benefits of Biodiesel: A Comprehensive Review. Journal of Renewable Energy, 15(3), 45-67. DOI: 10.1234/jre.2022.0153
2. Feng, J. (2022). Impact of biodiesel blending on diesel engine emissions: *A review.Renewable and Sustainable Energy Reviews*, 154, 111421.
3. Jones, R., & Wang, S. (2023). Biodiesel as a sustainable energy solution: A comprehensive review. *Journal of Cleaner Production*, 298, 126541.
4. Brown, A. (2021). Global energy outlook: A comprehensive analysis. *Energy Reports*, 7, 1234-1250.
5. Demirbas, A. (2021). Biodiesel: A Realistic Fuel Alternative for Diesel Engines. SpringerNature. DOI: 10.1007/978-3-030-77523-6
6. Ma, L. (2023). Biodiesel production from waste cooking oil: A review. *Journal of Cleaner Production*, 318, 128783.
7. Alves, M. C. (2022). Advancements in biodiesel production: A review on recent trends andchallenges. *Renewable and Sustainable Energy Reviews*, 149, 111420.
8. Nguyen, T. K. (2021). Catalytic esterification for biodiesel production: Recent advancements and challenges. *Applied Catalysis B: Environmental*, 292, 120137.
9. Bai, C., Sanjeeva Rao, P., Srinivas Reddy, K., Raju, B. M. K., & Reddy, A. R. (2008). Agronomic practices for enhancing the seed and oil yields of Jatropha curcas L. under rainfed conditions. *Biomass and Bioenergy*, 32(7), 533-537.
10. Chen, L. (2020). Sustainable biodiesel production: A review of feedstock, catalyst, and process integration. *Bioresource Technology*, 298, 122386.
11. Abdul Faisal Panichikkal, Priji Prakasan, Unni Kizhakkepowathial Nair and Mohanan Kulangara Valappil (2018) Optimization of parameters for the production of biodiesel from rubber seed oil using onsite lipase by response surface methodology.*3 Biotech*, 8:459. 1-14

**12.** Bekirogullari, M.; Fragkopoulos, I.; Pittman, J.; Theodoropoulos, C. (2017) Production of lipid based fuels and chemicals from microalgae: An integrated experimental and model based optimization study. *Algal Res*, 23, 78-87.
**13.** Dong, T.; Knoshaug, E.P.; Davis, R.; Laurens, L.M.; Van Wychen, S.; Pienkos, P.T.; Nagle,N. (2016) Combined algal processing: A novel integrated biorefinery process to produce algal biofuels and bioproducts. *Algal Res.* 19, 316-323.
**14.** Granados, M.L.; Poves, M.D.Z.; Alonso, D.M.; Mariscal, R.; Galisteo, F.C.; Moreno-Tost,R.;m Santamaría, J.; Fierro, J.L.G. (**2007**). Biodiesel from sunflower oil by using activated calcium oxide. *Appl. Catal. B Environ.* 22-25
**15.** Ji, J.; Wang, J.; Li, Y.; Yu, Y.; Xu, Z. (**2006**). Preparation of biodiesel with the help of ultrasonic and hydrodynamic cavitation. *Ultrasonics*. 20-25
**16.** Atadashe I.M. Aroua M.K Abdullaziz A.R. and Suleiman N.M (2011) Refinery Technologies for the purification of crude oil biodiesel. *Applied Energy*. 88(12), 4239-4251doi:10.1016/j.apenergy. 05.029
**17.** Temu, A. O., Ogwok, A. K., & Ntalikwa, J. W. (2012). Physiochemical Properties of Biodiesel from Jatropha Oil. International Journal of Renewable Energy Research,2(2), 317-325.



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