Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 13, Issue 1, 2025

Biodiesel Production from *Hura crepitans* Seed Oil: Effects of Reaction Parameters on Yield

*[1, 2]S.S. Adamu, [3]B.U. Bagudo, [2]M. Muhammad, [4]S. Umar, [2]Z.I.S.G. Adiya., [2]S. Yahahya, [5]I. Abdullahi. [1,2]I.B. Ibrahim

[1]Centre for Advanced Science Research and Analytical Services,
Usmanu Danfodiyo University, Sokoto, Nigeria.

[2]Department of Energy and Applied Chemistry, Usmanu Danfodiyo University, Sokoto, Nigeria.

[3]Department of Pure and Environmental Chemistry,
Usmanu Danfodiyo University, Sokoto, Nigeria.

[4]Department of Microbiology, Federal University, Birnin Kebbi, Nigeria.

[5]Department of Applied Chemistry, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria.

*Corresponding Author: samirashehuadamu@gmail.com.

Accepted: May 22, 2025. Published Online: May 30, 2025

ABSTRACT

This study investigated biodiesel production from *Hura crepitans* seed oil, focusing on the effects of temperature, catalyst amount, reaction time, and oil-to-methanol ratio on yield. The n-ZnO was synthesized by direct precipitation method using zinc nitrate [Zn- $(NO_3)_2.6H_2O$] and sodium hydroxide (NaOH) as precursor, while the oil extraction from *Hura crepitans* seeds was performed using the Soxhlet extraction method with n-hexane as the solvent. In addition, the experimental design was obtained from the response surface design on Minitab 17 statistical software. The results shows that optimal conditions for achieving high yields are at temperature of 65 °C, catalyst amount of 2.5-4 g, reaction time of 1.5 hours, and oil-to-methanol ratio of 1:8. Under these conditions, a maximum yield of 96.23% was achieved. The findings are consistent with recent studies on biodiesel production from various feedstock, thereby highlighting the potential of *Hura crepitans* seed oil as a sustainable feedstock for biodiesel production.

Keywords: Biodiesel production, *Hura crepitans* seed oil, transesterification, sustainable energy.

INTRODUCTION

The increasing demand for energy, coupled with concerns over climate change and fossil fuel depletion, have sparked interest in renewable energy sources [1]. Biodiesel, a biodegradable and

non-toxic fuel, has emerged as a promising alternative to conventional diesel fuel [2]. Derived from vegetable oils or animal fats, biodiesel offers a sustainable solution to reduce greenhouse gas emissions and dependence on fossil fuels [3]. *Hura crepitans,* commonly known as the sandbox tree, is a tropical plant species with seeds rich in oil. Recent studies have highlighted the potential of non-edible oils, such as those from *Hura crepitans*, for biodiesel production due to their favorable fatty acid composition and sustainability [4, 5]. Utilizing *Hura crepitans* seed oil for biodiesel production could provide a new avenue for sustainable energy generation, particularly in tropical regions where the plant is abundant.

Previous studies exist on the potential of *Hura crepitans* as a feedstock for biodiesel production, using calcined snail shell (CSS) and potassium hydroxide (KOH) [6], alkali-catalytic transesterification method [7] and hexane [8] as catalysts. Using n-ZnO as a catalyst in this research could contribute to the development of sustainable biodiesel production processes and promote the use of renewable energy sources [9].

This study investigates the potential of *Hura crepitans* seed oil as a feedstock for biodiesel production using n-ZnO as catalyst, whereas the experimental design was obtained from the response surface design on Minitab 17 statistical software, thereby investigating reaction conditions to achieve high yields and quality of biodiesel.

MATERIALS AND METHODS

Chemicals and reagents

All chemicals and reagents utilized in this study, including n-hexane (99.9%), methanol (99.9%), zinc nitrate (99.8%) and sodium hydroxide (98%), were of analytical grade and sourced from British Drug House (BDH). These chemicals were used without further purification, ensuring consistency and reliability in the experimental procedures.

Sample and sample collection

Hura crepitans (Sandbox tree) seeds were sourced from within Sokoto metropolis. The seeds were dried and pulverized into a fine powder to enhance oil extraction efficiency.

Catalyst preparation

The n-ZnO was synthesized by direct precipitation method using zinc nitrate [Zn $(NO_3)_2.6H_2O$] and sodium hydroxide (NaOH) as precursor. In this method, aqueous solution of sodium hydroxide (0.4 M) was slowly added to the aqueous solution of zinc nitrate (0.2 M) at room

temperature under vigorous stirring until white suspended precipitate was formed. The white product obtained was centrifuged at 5000 rpm for 20 min. It was washed three times with distilled water and lastly, absolute alcohol. The product was calcined at 500 °C for 3 h [10].

Oil extraction

The oil extraction from *Hura crepitans* seeds was performed using the Soxhlet extraction method with n-hexane as the solvent. A 20 g sample of powdered seeds was placed in a cellulose thimble, covered with cotton wool, and inserted into the Soxhlet extractor. The extraction was carried out at 60 °C for 3 hours using 100 cm^3 of n-hexane. After extraction, the thimble was removed, and the oil-containing flask was dried in an air oven at 65 °C for 30 minutes to remove residual n-hexane. The oil yield was then calculated gravimetrically using the equation (1) as described by Giwa et al. [10].

$$\% \text{ Oil yield} = \frac{\text{Weight of extracted oil (g)}}{\text{Weight of sample (g)}} \times 100 \quad (1)$$

Transesterification process

The transesterification reaction was conducted in a two neck round bottom flask (250 cm^3) equipped with reflux condenser, temperature controller and magnetic stirrer. Suspended solution of methanol (5.64 g) and the n-ZnO (2.5 g) catalyst was added to the warmed oil (50 g) in the reactor. The reactor was then placed on the water bath and the reaction conditions were maintained with constant stirring at 300 rpm. After the reaction was completed, the catalyst was removed from reaction mixture by centrifugation. The content was transferred into a separatory funnel and allowed to settle for 24 h. This permitted the glycerol to settle down since it is denser than the biodiesel. The glycerol was removed from the separatory funnel [11, 12]. The same method was adopted for the transesterification of each run based on the design of the experiment in Table 1. The percentage yield of biodiesel was calculated using equation (2).

$$\%\text{Biodiesel yield} = \frac{\text{Weight of biodiesel}}{\text{Weight of oil}} \times 100 \quad (2)$$

Purification of the biodiesel

The biodiesel underwent a triple washing process with warm distilled water to remove impurities such as residual glycerol, alcohol, catalyst, and soap. Subsequently, it was dried over anhydrous

sodium sulfate and filtered to ensure purity and quality, aligning with established biodiesel purification protocols [4, 11].

Experimental design

The experimental design was achieved by using response surface design on Minitab 17 statistical software. The effect of four factors i.e. reaction temperature, catalyst loading, reaction time and oil to MeOH ratio on the biodiesel yield were determined.

Table 1: Experimental design

Standard Order	Run Order	Temperature (°C)	Catalyst (g)	Reaction Time (H)	Oil to MeOH
52	1	65	2.5	1.5	1:6
19	2	50	2.5	2	1:6
11	3	50	2.5	1.5	1:8
8	4	65	2.5	2	1:8
1	5	50	2	1.5	1:6
24	6	65	4	1.5	1:8
40	7	65	1	1	1:6
33	8	65	2.5	2	1:4
31	9	80	4	1.5	1:6
51	10	65	4	1.5	1:8
2	11	80	1	1.5	1:6
12	12	80	2.5	1.5	1:8
48	13	65	1	1.5	1:4
43	14	65	4	2	1:6
36	15	50	2.5	1.5	1:4
18	16	80	2.5	1	1:6
28	17	50	1	1.5	1:6
37	18	80	2.5	1.5	1:4
49	19	65	4	1.5	1:4
29	20	80	1	1.5	1:6
53	21	65	2.5	1.5	1:6
23	22	65	1	1.5	1:8
17	23	50	2.5	1	1:6
16	24	65	4	2	1:6
30	25	50	4	1.5	1:6
46	26	50	2.5	2	1:6
39	27	80	2.5	1.5	1:8
44	28	50	2.5	1	1:6
32	29	65	2.5	1	1:4
35	30	65	2.5	2	1:8
25	31	65	2.5	1.5	1:6

6	32	65	2.5	2	1:4
41	33	65	4	1	1:6
9	34	50	2.5	1.5	1:4
21	35	65	1	1.5	1:4
42	36	65	1	2	1:6
26	37	65	2.5	1.5	1:6
50	38	65	1	1.5	1:8
47	39	80	2.5	2	1:6
3	40	50	4	1.5	1:6
13	41	65	1	1	1:6
7	42	65	2.5	1	1:8
4	43	80	4	1.5	1:6
20	44	80	2.5	2	1:6
15	45	65	1	2	1:6
34	46	65	2.5	1	1:8
5	47	65	2.5	1	1:4
38	48	50	2.5	1.5	1:8
14	49	65	4	1	1:6
45	50	80	2.5	1	1:6
54	51	65	2.5	1.5	1:6
22	52	65	4	1.5	1:4
10	53	80	2.5	1.5	1:4
27	54	65	2.5	1.5	1:6

RESULTS AND DISCUSSION

Biodiesel yield

The experimental design and results of the percentage biodiesel yield as shown in Table 2 include the resulting biodiesel yield percentage temperature, catalyst amount, reaction time and oil-to-methanol ratio.

Table 2: Experimental design and biodiesel yield

Standard Order	Run Order	Temperature (°C)	Catalyst (g)	Reaction Time (H)	Oil to MeOH	%Yield (%)
52	1	65	2.5	1.5	1:6	93.68
19	2	50	2.5	2	1:6	87.33
11	3	50	2.5	1.5	1:8	89.45
8	4	65	2.5	2	1:8	95.81
1	5	50	2.5	1.5	1:6	87.15
24	6	65	4	1.5	1:8	96.23
40	7	65	1	1	1:6	89.02
33	8	65	2.5	2	1:4	90.12
31	9	80	4	1.5	1:6	56.37
51	10	65	4	1.5	1:8	95.90
2	11	80	1	1.5	1:6	55.90
12	12	80	2.5	1.5	1:8	59.21
48	13	65	1	1.5	1:4	90.44
43	14	65	4	2	1:6	94.06
36	15	50	2.5	1.5	1:4	84.37
18	16	80	2.5	1	1:6	57.81
28	17	50	1	1.5	1:6	85.16
37	18	80	2.5	1.5	1:4	52.50
49	19	65	4	1.5	1:4	92.78
29	20	80	1	1.5	1:6	55.33
53	21	65	2.5	1.5	1:6	94.84
23	22	65	1	1.5	1:8	91.05
17	23	50	2.5	1	1:6	86.75
16	24	65	4	2	1:6	94.17
30	25	50	4	1.5	1:6	88.93
46	26	50	2.5	2	1:6	87.41
39	27	80	2.5	1.5	1:8	60.10
44	28	50	2.5	1	1:6	86.85
32	29	65	2.5	1	1:4	92.14
35	30	65	2.5	2	1:8	94.21
25	31	65	2.5	1.5	1:6	92.41
6	32	65	2.5	2	1:4	91.99
41	33	65	4	1	1:6	93.45

9	34	50	2.5	1.5	1:4	86.17
21	35	65	1	1.5	1:4	89.99
42	36	65	1	2	1:6	91.10
26	37	65	2.5	1.5	1:6	92.63
50	38	65	1	1.5	1:8	90.47
47	39	80	2.5	2	1:6	58.23
3	40	50	4	1.5	1:6	88.76
13	41	65	1	1	1:6	89.95
7	42	65	2.5	1	1:8	94.75
4	43	80	4	1.5	1:6	56.45
20	44	80	2.5	2	1:6	54.98
15	45	65	1	2	1:6	90.33
34	46	65	2.5	1	1:8	93.92
5	47	65	2.5	1	1:4	91.51
38	48	50	2.5	1.5	1:8	87.39
14	49	65	4	1	1:6	95.50
45	50	80	2.5	1	1:6	55.57
54	51	65	2.5	1.5	1:6	91.31
22	52	65	4	1.5	1:4	92.88
10	53	80	2.5	1.5	1:4	53.11
27	54	65	2.5	1.5	1:6	94.30

The relationship between temperature and %Yield at 50 °C yields range from approximately 84% to 89%. At 65 °C yields (Figure 1) are generally higher, ranging from approximately 89% to 96%. At 80 °C yields are significantly lower, ranging from approximately 52% to 60%. This suggests that 65 °C is the optimal temperature for achieving high yields and is in agreement with the research carried out by Oraegbunam et al. [13].

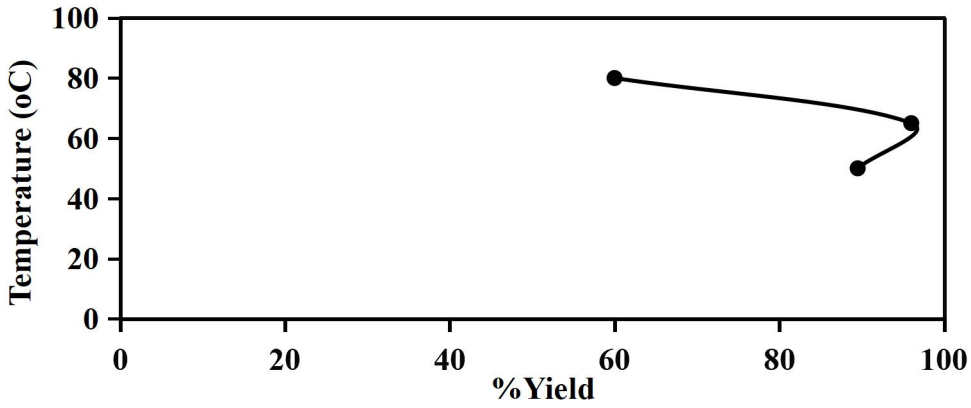

Figure 1: Temperature vs %Yield of the biodiesel

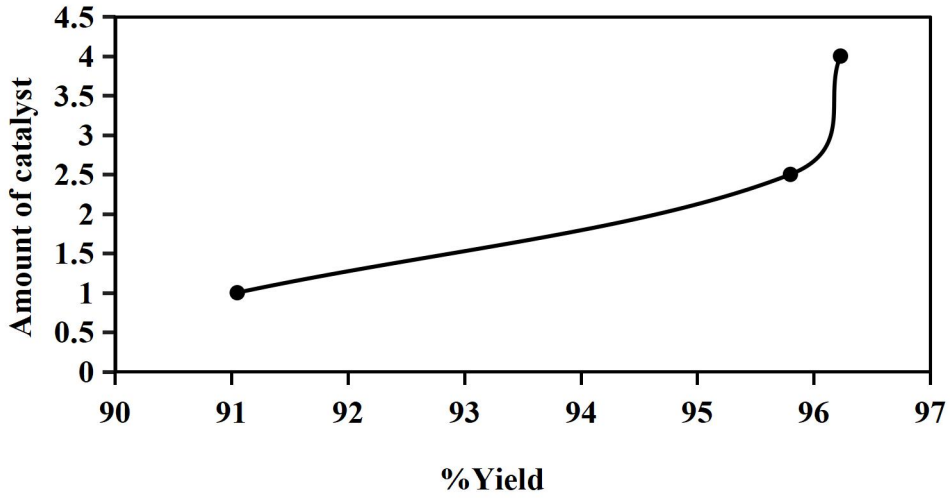

Figure 2: Amount of catalyst vs %Yield of the biodiesel

The relationship between catalyst amount and %Yield is shown in Figure 2. This indicates that increasing the catalyst amount tends to increase yields, but the effect may plateau beyond a certain point. Increasing the catalyst amount from 1 g to 2.5 g and then to 4 g results in higher %Yields, specifically 91.05%, 95.8%, and 96.23%, respectively. The results suggest that using 4 g of catalyst yields the highest result, but the difference between 2.5 g and 4 g is relatively small, indicating that 2.5 g might be a sufficient amount. The amount of catalyst used significantly affects the yield, with higher amounts generally resulting in higher yields. Further

variation of catalyst amount might lead to even higher yields or more efficient use of resources. The result is in agreement with the findings reported by Ulakom et al. [7].

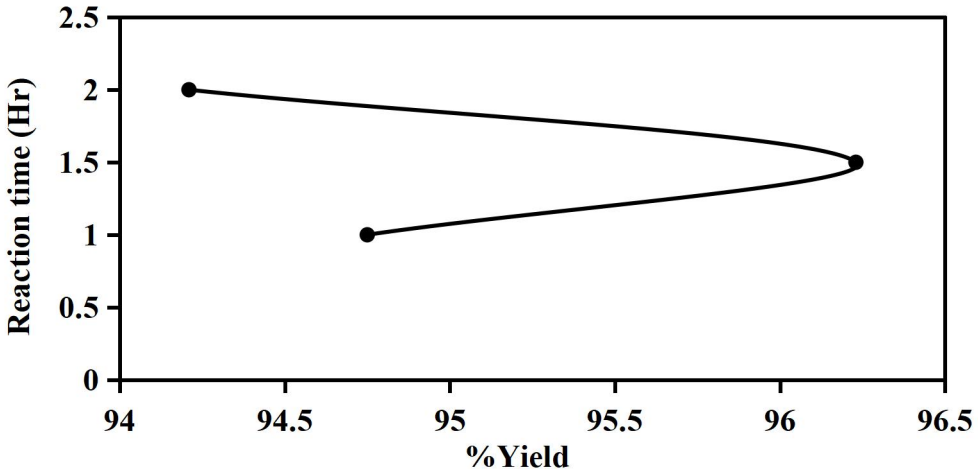

Figure 3: Reaction time (Hr) vs %Yield of the biodiesel

Figure 3 shows the relationship between reaction time and %Yield. Yield on 1.5 hours is the highest result, with a %Yield of 96.23%. This suggests that 1.5 hours is the optimal reaction time for achieving high yields. The yields at 1 hour (94.75%) and 2 hours (94.21%) are slightly lower than the optimal yield at 1.5 hours. This indicates that 1.5 hours is a suitable reaction time for achieving high yields. This result corroborates with the work carried out by Ulakom et al. [7]. The reaction time significantly affects the yield, and optimizing this parameter can lead to higher yields.

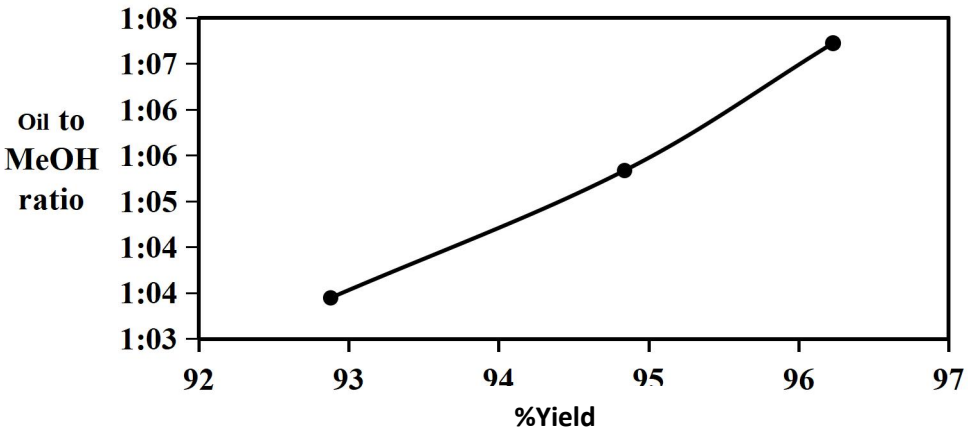

Figure 4: Oil to MeOH ratio vs %Yield of the biodiesel

The ratio of oil to MeOH significantly affects the yield, and optimizing this parameter can lead to higher yields. As shown in Figure 4, the relationship between oil-to-methanol (MeOH) ratio and %Yield, indicates that the highest yield (96.23%) is achieved at a 1:8 oil-to-MeOH ratio. As the MeOH ratio increases from 1:4 to 1:8, the yield also increases, suggesting that a higher MeOH ratio favors the reaction.

This result is in conformity with research of recent studies on biodiesel production from various feedstock reported by Kumar et al. [2] on biodiesel production from waste cooking oil in which a maximum yield of 94.5% was achieved at 60 °C, 3 g catalyst, and 1:6 oil-to-MeOH ratio. Also, Singh et al. [3] reported a yield of 92.1% from *Jatropha curcas* oil at 65 °C, 2.5 g catalyst, and 1:8 oil - to-MeOH ratio, and Atabani et al, [4] achieved a yield of 95.6% from *Moringa oleifera* oil at 60 °C, 4 g catalyst and 1:6 oil-to-MeOH ratio.

CONCLUSION

The study demonstrated that *Hura crepitans* seed oil is a promising feedstock for biodiesel production, with optimal conditions identified as 65 °C, 2.5-4 g catalyst, 1.5 hours reaction time, and 1:8 oil-to-methanol ratio. The results are consistent with previous studies, and the high yield achieved under optimal conditions suggests that *Hura crepitans* seed oil can be a viable alternative for sustainable biodiesel production. Further research can focus on scaling up the process and exploring the economic and environmental feasibility of using *Hura crepitans* seed oil for biodiesel production.

REFERENCES

[1] International Energy Agency. (2023). World Energy Outlook 2023.

[2] Kumar, P., Singh, R. K., & Chaudhary, N. (2022). Waste engine oil: A potential source of energy and environmental concerns. *Journal of Cleaner Production*, 344, 130934.

[3] Singh, D., Sharma, Y. C. & Upadhyay, S. N. (2023). Waste engine oil recycling: A review of current trends and future directions. *Fuel,* 331, 125790.

[4] Atabani, A. E., Mahlia, T. M. I., AnjumBadruddin, Irfan, Anjum, Waqas, M. & Silitonga, A. S. (2022). Recent advances in biodiesel production and its applications. *Renewable Energy*, 181, 1194-1209.

[5] Sivakumar, P., Sindhu, R. & Parameswaran, B. (2023). Optimization of biodiesel production from non-edible oil using response surface methodology. *Renewable Energy,* 202, 142-153.

[6] Oyelade, J. O., Idowu, D. O., Oniya, O. O. & Ogunkunle, O. (2017). Optimization of biodiesel production from sandbox (*Hura crepitans* L.) seed oil using two different catalysts. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 39, 12, 1242-1249, DOI: 10.1080/15567036.2017.1320691

[7] Ulakom, S., Ezekoye, V., Ofomatah, A., Ezekoye, D. & Agbogu, A. (2022). Extraction and Characterization of *Hura crepitans* Seed Oil. *Journal of Nano and Materials Science Research*, *1*, 1–8. https://doi.org/10.20221/jnmsr.v1i.2

[8] Adewuyi, A., Awolade, P.O. & Oderinde, R.A. (2017). *Hura crepitans* Seed Oil: An Alternative Feedstock for Biodiesel Production, *Journal of Fuels* Volume 2014, Article ID 464590, 8 pages. http://dx.doi.org/10.1155/2014/464590

[9] Kumar, R., Singh, S. K. & Tyagi, V. V. (2023). Biodiesel production from non-edible oils: A review. *Fuel,* 331, 125790.

[10] Giwa, S. O., Adekomaya, O. S., Nwachukwu, C. A. & Yusuf, E. O. (2022). Production of biodiesel from non-edible oils: A review. *Fuel*, 310, 122345.

[11] Silitonga, A. S., Masjuki, H. H., Mahlia, T. M. I., Ong, H. C., Chong, W. T. & Boosroh, M. H. (2021). A review on biodiesel production from various feedstocks. *Renewable and Sustainable Energy Reviews*, 137, 110472.

[12] Pathak, P. K., Singh, V. K., Kumar, S. & Singh, B. (2022). Recent advances in biodiesel production: A review. *Fuel,* 310, 122345. doi: 10.1016/j.fuel.2021.122345.

[13] Oraegbunam, E. O., Nwosu, F. O. & Okoro, V. O. (2023). Optimization of biodiesel production from seed oil: A parametric study. *Journal of Renewable Energy Research,* 12(3), 245-255.