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Optimization and Characterization of Biodiesel Production from Desert Date Seed Oil (*Balanites aegyptiaca*) via Transesterification Reaction

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Abstract

In recent years, the combustion of petroleum-based fuels has caused harmful exhaust emissions, contributing to the escalation of global warming and the greenhouse effect. Consequently, the urgency for alternative fuels has grown in our constantly evolving world. Furthermore, traditional fossil fuels like coal, petroleum, and natural gas are being depleted at a steady pace. Despite this depletion, the world's dependence on these fuels continues to increase. This pressing issue has sparked research focused on the production of biodiesel from desert date seed oils, which are both easily accessible and environmentally friendly. The study involved the transesterification of desert date seed oil, using methanol as the alcohol and NaOH as the catalyst for the reaction. The optimization process employed response surface methodology (RSM) with the Box-Behnken approach, utilizing Design Expert 13 software. The analysis of the resulting biodiesel closely matched standard values, affirming that the liquid derived from the transesterification process of desert date seed oil was indeed biodiesel. The yield of this process was 92%, consistent with the findings of Giwa et al. (2016) who reported a yield of 82%.

1. Introduction

The finite nature of petroleum-derived fuels, global energy crisis and climate change, have necessitated the search for green bio-fuels that are renewable, eco-friendly and can serve as substitute to Petro-derived fuels. In this regard, bio-ethanol and biodiesel are believed to have great potential and a promising future, especially for the transportation sector. As a result, research interest is being focused on this area [1]. Growing concern due to environmental pollution caused by conventional fossil fuels and their depletion has led to a search for more environmentally friendly and renewable fuels, among various options investigated for diesel fuel, biodiesel obtained from vegetable oils and other sources has been recognized worldwide as one of the best alternatives for reducing exhaust emissions [2]

Biodiesel, as an alternative fuel, has been currently receiving much attention owing to the limited availability of conventional petroleum diesel and environmental concerns. It can be directly used to replace petroleum diesel without modifying diesel engines since their properties, e.g., specific gravity, cetane number, viscosity, cloud point, and flash point, are similar, It is a promising alternative or extender to conventional petroleum-based diesel fuel. Furthermore, it has a number of advantages such as reducing carbon dioxide emissions by about 78%, nontoxicity and biodegradability. These its benefits have made the fuel a very good environmentally benign one. Furthermore, biodiesel is a renewable energy source [3]

The first American Society for Testing and Materials (ASTM D6751) was published in 2002. In October of the following year, a new biodiesel standard DIN EN14214 was published in Europe. Later in September of the next year The U.S. state of Minnesota sold the diesel fuel that contained 2% biodiesel and then in 2008 October ASTM published the first biodiesel blend specification standard. The present version of the European standard EN 14214 was published in November 2008 [4].

Balanites aegyptiaca belongs to the Kingdom: Plantea; Division: Spermatophyta; Subdivision: Angiospermea; Class: Dicotyledonea; order: Balanitales; family: Balanitaceae; Genus: Balanites; Species: aegyptiaca; [5] Balanites aegyptiaca tree is distributed in West Africa, especially in West African arid and semi-arid regions where the climatic environment and soil are not suitable to produce plants commonly used for the production of biofuel, In Nigeria, Balanites aegyptiaca is commonly found in the northern part of the country with mean temperature of 20-30°C and mean annual rainfall of 250-400 mm3, It is one of the most neglected common trees, usually found throughout the dried regions of Africa, especially Nigeria [6].

From past literature works especially [7] produced and characterize the oil from the seed, [3] & [4], these author only produced biodiesel, [8] the author produced biodiesel and characterize the biodiesel, [5] produced the biodiesel from a heterogenous catalyst, [9] optimized the production, and finally [10] optimized the oil extraction by using D-Optimal method but this study is centralized on the optimization of the biodiesel production using response surface methodology and the method is ***Box-Behnken Design*** using design expert and display the physio-chemical properties which is also the fuel properties of the biodiesel to see if its fit for mass production.

2. Material and Methods

2.1 Materials

The materials used in the current study include a magnetic stirrer, ground sample of the Balanites aegyptiaca seed kernel., N-hexane, methanol, vegetable oil extracted from the plant's seed kernel, sodium hydroxide pellets (caustic soda), Soxhlet extractor was the equipment used for the oil extraction. Brookfield viscometer was used to determine the kinematic viscosity, other equipment used for oil extraction and biodiesel production includes: electronic weighing balance, water bath shaker

2.2 Methods

The aim of this experiment was to extract oil from the sample according to the following procedure. 100g of the seed sample was weighed using electric weighing balance and placed into the thimble of the Soxhlet extraction apparatus. 175ml of n-hexane solvent was poured into the

thimble and allowed to extract the oil at 68°C for about 2-4 hours. The extract (mixture of oil and solvent) was then taken to an oven which facilitates evaporating of the solvent and the pure oil was obtained.
One hundred (100) ml of the oil was measured and poured into a 250 ml conical flask and heated to a temperature of 50°C using a water bath. A solution of sodium methoxide was prepared in a 150ml beaker using 0.08g of NaOH pellet and 19ml of methanol. The sodium methoxide solution produced was then poured gently into the warm oil and stirred vigorously for about 90 minutes using a water bath shaker. The mixture was then poured in a separating funnel and allowed to settle for about 24 hours. After settling, the upper layer (biodiesel) was decanted into a separate beaker while the lower layer which consists of glycerol and soap were collected from the bottom of the funnel. The decanted biodiesel was washed with warm water of about 45°C in order to eliminate soluble methanol, excess catalyst and other impurities. The washing process left the biodiesel looking a bit cloudy which indicated the presence of moisture. The biodiesel was heated slowly to a temperature slightly above 105°C in the oven until all moisture present evaporated.
Response surface methodology (RSM) with Box-Behnken module was applied to optimize is to maximize production of biodiesel from Mango, Desert date and the blend of both oils using 'Design Expert®' (Version 13.0.0, Stat Ease, Inc., USA) software. In this study four factors were considered which are methanol to oil ratio, catalyst loading, Temperature and reaction time.

Table 1: Independent factors used for Box-Behnken in transesterification of the extracted oil

Variables	Low	High	Unit
Temperature	35	75	^{O}C
Time	60	180	Minutes
Catalyst Concentration	0.3	0.7	%wt/vol
Methanol to Oil Ratio	3:1	9:1	vol/vol

3.Results and Discussions

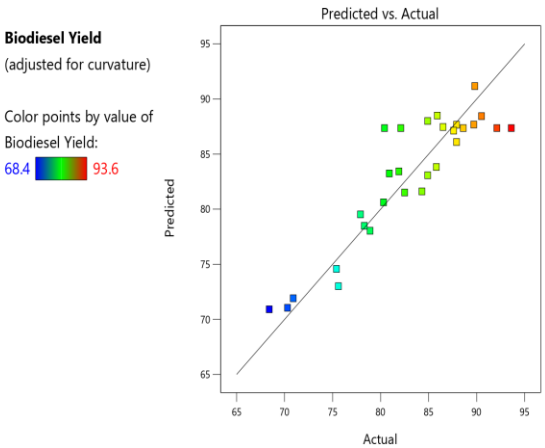
Table 2 shows the different physical and chemical parameters of Balanites aegyptiaca seeds oil. From the results it was observed that Balanites aegyptiaca seeds oil is potential seed oil for the production of biodiesel. The seed oil has a considerable yield, the saponification, iodine and free fatty acid value falls within the range of vegetable oils suitable for biodiesel production. The oil showed a lower moisture content and non-drying characteristic which can be considered suitable for biodiesel production.

Table 2: Physiochemical properties of desert date seed oil

Property	**Unit**	**Astm**	**Desert date oil**
Specific gravity	-	0.957– 0.968	0.907
Saponification Value	MgKOH/g	175-187	216
Iodine value	gI_2/100g oil	82-88	63.53
Acid value	mgKOH/g	0.4-4.0	3.06
Viscosity	Cst	35	19.68

Refractive index	-	-	1.458
Peroxide value	meq/kg	5.00	9.4
PH Value	-	-	-
S%FFA	wt. %	25	1.27
Density	g/cm^3	0.7-0.95	0.910
Molecular weight	-	300-314	790.36

Figure 1 shows the graph of the predicted value vs the actual values obtained in the transesterification of desert date oil. It was observed that the difference between the actual was not far off from the predicted value that is why they are in alignment to the straight line. And looking at the normal plot of residual, they all fall on the line of the plot which makes the residual more aligned which the difference between the actual and the predicted values in figure 2.



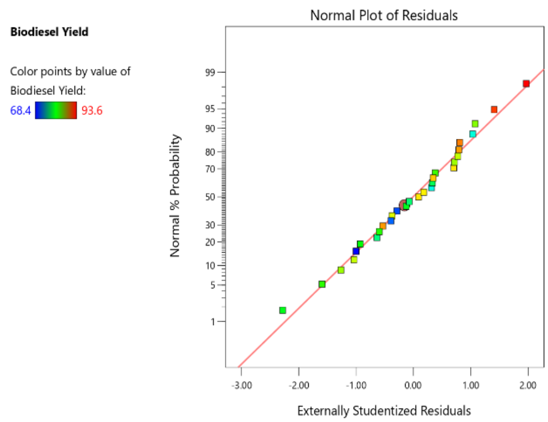
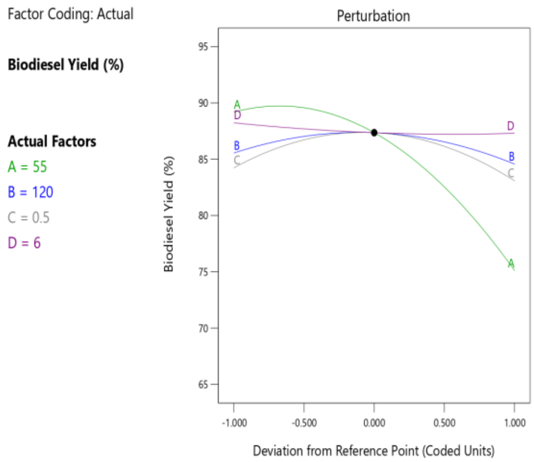


Figure 1: Predicted values vs. actual values **Figure 2: Normal Plot of Residuals**

In figure 3, the perturbation graph shows the relationship between all the independent factors. The plot of the biodiesel against the deviation from reference point. On the graph, the point where all the independent factors meet, when traced down to the deviation reference point it shows 0.000 and it's traced to the side of the biodiesel, it is within the range of 85% - 90% but its 87% which it's in alignment to the best experimental factors gotten during the production of the biodiesel.



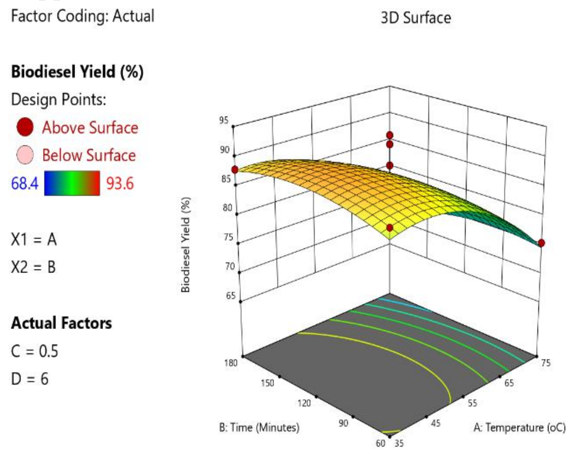


Figure 3: Perturbation.

Figure 4: Response surface plot of the interaction effect of reaction time and reaction temperature

Table 3: Physiochemical properties of desert date biodiesel

Property	Unit	ASTM (D6751)	ASTM (D975)	EN 14214	Desert Date biodiesel	Usman & Rufai (2020)
Specific gravity	-	0.957–0.968	1.9-4.1	3.5-5.0	0.89	4.7
Saponification Value	MgKOH/g	-	-	-	188.42	216
Iodine value	gI_2/100g oil	-	-	120 max	44.83	68.53
Acid value	mgKOH/g	≤ 0.8	-	0.50 max	5.28	0.11
Kinematic Viscosity @40	mm^2/s	1.9-6.0	-	-	15.26	-
Cetane Number	-	47 min	52 min	-	-	50.42
Peroxide value	meq/kg	5.00	0.01	-	7.12	1.4
Density	g/cm^3	0.7-0.95	-	0.86-0.90	0.90	0.886
Flash Point	^OC	130 min	-	-	165	-
Ash Content	%	-	0.01	-	0.03	-
Pour Point	^OC	-15 to 10	-	-	12	-
Cloud point	^OC	-	-	-	-	-

Table 3 shows the values of Desert date biodiesel is being compared to the standards and some literature works.

4. Conclusion

After the optimum results was achieved, it was concluded that the industrial utilization of Balanites aegyptiaca oil for the production of biodiesel is favourable because of its oil yield capacity from the plant and its limitation for utilization as edible oil. The promising plant having oil yield of 396 g/kg (42%) with 88% extraction efficiency revealed high oil yield, and fact that the Soxhlet extractor could extract about 88% of the available oil present in the seed. The predicted biodiesel yield for the desert date biodiesel was 93.125% with a reaction temperature of 36.98^{o}C, reaction time of 104 minutes, catalyst concentration of 0.38 and methanol to oil ratio of 9:1. However, after performing the experiment 5 times, the actual biodiesel yield achieved was 92.47% with a standard deviation of 0.655.

Reference

[1] Nnaji, J.C. (2020), Advances in Biodiesel Synthesis: The role of various catalyst, *Open Journals for Engineering sciences*,1(10), 53-71.

[2] Onukwuli, D.O., Umeuzuegbu, J.C., Ude, C.N., Nwobi-Okoye, C.C. (2020), Homogeneous catalyzed transesterification of neem seed oil to biodiesel and its kinetic modelling, *Wiley Online Library (wileyonlinelibrary.com);* DOI: 10.1002/bbb.2171; Biofuels, Bioprod. Bioref.

[3] Giwa, S.O., Ibrahim, M., Akaagerger, S.M., & Giwa, A. (2016). Production of Biodiesel from Desert Date Seed Oil. *International Journal of ChemTech Research*, *9*(6), 453-463

[4] Mahmudul, H.M., Hagos, F.Y., Mamat, R., Adam, A.A, Ishak, W.F.W, Alenezi, R. (2017), Production, characterization and performance of biodiesel as an alternative fuel in diesel engine-A review, *Renewable and Sustainable Energy Review, 72*(2017), 497 – 509, dx.doi.org/10.1016/j.rser.2017.01.001

[5] Dass, P.M., Louis, H., Alheri, A.1., Amos, P.I., Bifam, M. & Ago, M.A. (2018). Production of Biodiesel Oil from Desert Dates (*Balanites aegyptiaca*) Seeds Oil Using a Hetrogeneous Catalyst Produced from Mahogany (*Khaya senegalensis*) Fruit Shells. *Analytical Chemistry Indian Journal*, *18*(1), 129Bambara, L.D.F., Sawadogo, M., Roy, D., Anciaux, D., Blin, J., & Ouiminga, S.K., (2018), Biofuel from Balanites aegyptiaca: Optimization of the Feedstock Supply Chain, *Sustainability*, 10, 4501; doi:10.3390/su10124501

[6] Usman, A., Rufai, I.A. (2020), Properties of Balanites Aegyptiaca Biodiesel as a potiential energy carrier in the dryland of Nigeria, *International Journal of Energy Engineering*, 10(4), 95-101, DOI: 10.5923/j.ijee.20201004.01

[7] Ogala, H., Elinge, C.M., Wawata I.G., Adegoke, A.I., Muhammad, A.B., & Ige, A.R., (2018), Extraction and Physicochemical Analysis of Desert Date (*Balanite Aegyptiaca*) Seed Oil, *International Journal of Advanced Academic Research | Sciences, Technology & Engineering* | ISSN: 2488-9849 Vol. 4, Issue 4.

[8] Kamil, M., Ramadan, K., Olabi, A.G., Ghenai, C., Inayat, A., & Rajab, M.H., (2019), Desert Palm Date Seeds as a Biodiesel Feedstock: Extraction, Characterization, and Engine Testing, *Energies*, 12, 3147; doi:10.3390/en12163147

[9] Bambara, L.D.F., Sawadogo, M., Roy, D., Anciaux, D., Blin, J., & Ouiminga, S.K., (2018), Biofuel from Balanites aegyptiaca: Optimization of the Feedstock Supply Chain, *Sustainability,* 10, 4501; doi:10.3390/su10124501

[10] Giwa, S.O., Abdulyekeen, K.A., Ekwunife, I.F., Garba, K., & Giwa, A., (2022), D-Optimal Optimization of Desert Date Oil Extraction, ABUAD Journal of Engineering Research and Development (AJERD), 5(1), 22-30