OPTIMIZATION AND CHARACTERIZATION OF OIL EXTRACTED FROM BATATI AFRICAN PEAR SEED AS AN ALTERNATIVE BIODIESEL FEEDSTOCK

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ABSTRACT
This particular research dwells on the optimization and characterization of oil from African pear seed obtained from a plantation located at Batati village in Niger state of Nigeria. The sohxlet extraction method was employed and the extraction process was optimized using Box-Behcken Design (BBD) Response Surface Methodology (RSM). Three level coded factors used for the design are: Temperature of extraction (A), the Volume of n-hexane (B) and the extraction Time(C). Seventeen (17) runs were suggested by the design matrix generated using Design expert 13.0. The quadratic model was suggested which well fitted the experimental results with predicted R^2 value of 0.8314, adjusted R^2 value of 0.9691 and an adequate precision of 22.079. The optimum conditions for the oil extraction are Temperature of 80 ^{O}C, n-hexane volume of 150 ml and extraction time of 60 minutes which gives an optimum yield of 46.4 %. The fatty acids compositions of the extracted oil was determined using Gas Chromatograph and Mass spectrograph (GCMS) and the result showed that the total unsaturated fatty acids amount to 59.6 % comprising of mono-unsaturated Oleic acid with a composition of 38.86 % and di-unsaturated Linoleic acid with a fraction of 20.74 %. The total composition of saturated fatty acids stands at 40.4 % with palmitic acid having the greater value of 36.74 % while stearic acid is the least with a composition of 3.66 %. The Physicochemical properties of the oil were determined using ASTM standard methods and the results revealed that and the pH is 6.7 while the density, specific gravity, refractive index, free fatty acid and viscosity are: 0.8419 Kg/m^3, 0.8882, 1.336, 4.443 % and 3947.9 mPas respectively. The Smoke point, Fire point and Flash point of the oil were 74, 85 and 95 ^{O}C respectively, and the acid value, saponification value and peroxide value recorded are 8.886, 213.18 and 25 (mgKOH/g) respectively. From the results of the percentage yield and characterization of the oil, it can be used as a viable alternative feedstock for biodiesel manufacture.

Key words: Optimization, Characterization, African pear seed and Extraction.

1.0 INTRODUCTION

African pear (*Dacryodes. edulis*) is a fruit bearing tree of Africa origin and most part of it that is utilized is the fruit. It spreads along the Atlantic Ocean in five countries that includes Congo, Gabon, Equatorial Guinea, Cameroon and Nigeria (Todou *et al*., 2013). It has a height of 18-40 m consisting of alternate compound leaves of 5-8 pairs of leaflets and yellow flowers (Ajibesin, 2011) The French call it 'Safou' while the central Africans call it 'Atanga'. In Nigeria, the Igbo name it Ube and at the same time called 'Elemi in Yoruba dialect (Helene and Joseph, 2021). The Nupe people from Niger state of Nigeria where the sample used for this particular research was collected call it Esha. In Nigeria trees are predominant in the south eastern part of the country where the trees are found growing around homesteads. The flower formation occurs between January and April while fruiting takes place between May and October.

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The variety found in this area produce an annual fruit of about 3cm in diameter covered by a leathery thin skin covering a pulpy pericarp of about 5mm thick. The pulp is found to contains 48% oil and about 7-8 tonnes of oil can be obtained per hectare of plantation can produce. This makes it useful as feedstock for biodiesel production (Ogunsuyi and Oyeni, 2018). The trees are also found in the North central region specifically in Niger state and also in the south Western region of the country.

The part of the fruit that is consumed is the pulp which is roasted, boiled or eaten raw. The cooked version of it looks like butter which can be used with bread. It is also used in garnishing roasted maize and cooked Cassava. The seed is usually discarded as waste (Duru *et al*., 2012).

There is no distinct classification among African pear varieties (Helene and Joseph, 2021). Some researchers, classified African pear into two different varieties based mainly on the size of fruit which are: large fruit with dimensions of more than 5 x 2.5 cm, with a thick pulp about 3.5-9 mm called *D. edulis* var. *edulis* and a smaller fruit with dimensions of less than 5 x 2.5 cm, with a thin pulp about 2-3.5 mm called *D. edulis* var. *parvicarpa* (Poligui *et al*., 2013; Kadji *et al*, 2016; Djedje *et al*. 2020) . The variability in Fruit chemical characteristics can be due to environmental factors such as climate, soil type, fertiliser application and farming practices (Youmbi *et al*., 2010).

As such more researches are needed on the morphological and physio-chemical properties of African pear trees from different locations in order to be able to classify it variability. Studies must also be carried out on the genetic transformation so as to confirm and identified classes corresponding and common to varieties of *D. edulis*.

The use of edible oils as feedstock for biodiesel production is a source of concern and a treat to food security as it threatens the food supply chain and results in high cost of edible oils due to high demand of these oils for commercial biodiesel production (Bull and George, 2015). This unacceptable act makes the biodiesel produced expensive (Ayhan *et al*., 2016). Therefore, researcher's efforts are directed towards identifying and evaluating indigenous non-edible seed oils as suitable feedstock for biodiesel production (Ogunsuyi and Oyeni, 2018).

Many researches has been carried on different accessions of African pear from the South Western and South Eastern part of Nigeria and none have been reported on the accession from the North Central region. As such, this particular research focuses on optimization and characterization of oil extracted from African pear seed obtained from Batati village located in Niger state of Nigeria (North Central region) to be compared with the report of other researchers that used samples from different locations and also to ascertain it viability as a feedstock for biodiesel production.

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2.0 METHODOLOGY

2.1 RSM Optimization of oil extraction

I Preliminary Investigations of Process Parameters

Three independent variables were considered for optimization in order to see their individual and combined effects on the yield (dependent variable) of APSO from it's seed. These variables are: Extraction temperature, volume of n-hexane (solvent) and the extraction time.

(a) Effect of extraction temperature on the yield of oil from African pear seed

Exactly 20 g of the seed was weighed and placed on the extraction thimble and placed in the extractor. Exactly 150 ml of n-hexane was in the distillation flask whose neck extractor which in turn connected to the condenser. The temperature of the heating mantle was set at 60 ^{O}C for the period of 30min. At the end of the extraction time, the content of the distillation flask was transferred to a rotary evaporator where the oil was recovered from the solvent. The oil recovered was then weighed and the weight recorded. The procedure was repeated at varying temperatures of 65, 70, 75, 80, 85 and 90 ^{O}C.

(b) Effect of volume of n-hexane temperature on the yield of oil from African pear seed

The procedure in I (a) was repeated at a constant temperature of 80 ^{O}C and extraction time of 30 minutes while the volume of n-haxane was varied using 100, 150, 200 and 250 ml.

(c) Effect of volume of n-hexane temperature on the yield of oil from African pear seed

The procedure in I (b) was repeated at a constant temperature of 80 ^{O}C and volume of n-haxane of 150 ml while the extraction time was varied using 30, 45, 60, 75 and 90 minutes.

I. OPTIMIZATION OF PROCESS PARAMETERS USING RESPONSE SURFACE METHODOLOGY (RSM)

The results from the preliminary investigation were used to design the experiment and three level factors which includes extraction temperature (A), solvent volume (B) and the extraction time (C) and their levels were considered. Box-Behnken Design (BBD) was adopted using design expert 13.0 which suggested 17 experimental runs. The experimental design was used to determine the yield of oil of each run experimentally. The experimental results were again feed back to the software and the optimum parameters were suggested for the maximum yield of oil. The average oil yield obtained at the optimum suggested parameters was compared with the one suggested by the model via standard deviation.

2.2 Characterization of APSO

(a) GCMS analysis of APSO

The GCMS analysis was carried out using GCMS analyzer Model no.-GC7890B 5977A MSD. The sample was dissolved in a solvent, ratio of 1:10 v/v, then filtered with micro filter Nylon 0.45μm and transferred in to a sample vial of about 2μl of the sample; it was then injected at 250 ^{O}C in the injection port and splitters at a rate of 5:1 before reaching the Gas Chromatographic column which was conditioned at an Oven set initially at 50 ^{O}C hold for 2mins at rate of 50 ^{O}C/min raised to 200 ^{O}C hold at 0 min, then at rate of 5 ^{O}C/min to 270 ^{O}C and finally hold for 5 min. The sample was volatilized and separated into various components of ions of mass to charge ratio m/z, then transferred to the mass selective detector. The resulting mass spectrum of the component were identified and qualified standard reference Library in the data analysis software which gives the compound names in respects to its quality comparison in percentage.

a) Physicochemical analysis of APSO

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The physicochemical properties analyzed includes: percentage yield, Density, specific gravity, viscosity, saponification value, peroxide value, acid value, percentage free fatty acid, pH, flash point, smoke point, fire point and refractive index using ASTM standard methods.

3.0 RESULTS AND DISCUSSIONS

3.1 Effect of Extraction Temperature on the Yield of Oil from African Pear Seed

The effect temperature of extraction was put to test in order to ascertain the upper and the lower limit of it to be used for the RSM optimization. The temperature was varied from a starting value of 60 ^{O}C with a step change of 5 ^{O}C to an upper value 90 ^{O}C. Figure 4.1 shows the results obtained of such investigation.

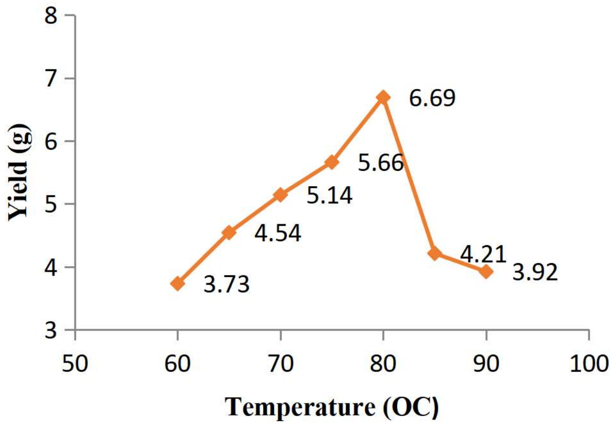

Figure1: Effect of temperature on the extraction of APSO

From the figure, the yield of oil increases steadily as the temperature increases from 60 to 80 ^{O}C with numerical values of 3.73, 4.54, 5.14, 5.66 and 6.69 g corresponding to extraction temperatures of 60, 65, 70, 75 and 80 ^{O}C respectively. As the extraction temperature exceeds 80 ^{O}C the yield began to decline with absolute values of 4.21 and 3.92 g obtained at extraction temperatures of 85 and 90 ^{O}C respectively. At these higher temperatures, some fraction of n-hexane escapes from the condenser thereby reducing the volume of solvent required to extract the oil.

3.2 Effect of Volume of n-Hexane on the Yield of Oil from African Pear Seed

Fixing the temperature of extraction at 80 ^{O}C and the extraction time of 30 minutes, the volume of n-hexane was varied between 100 to 250 ml with a step change of 50 ml. The results obtained is revealed in figure 4.2

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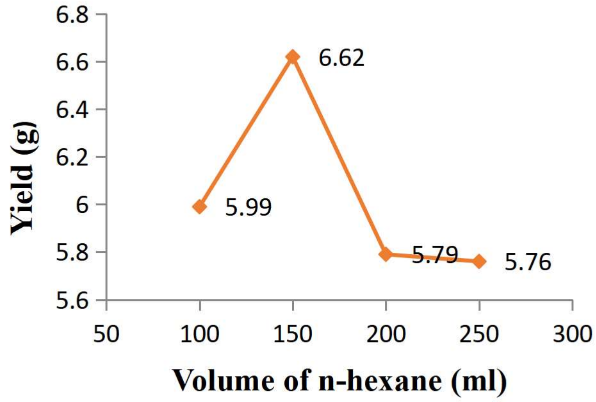

Figure 2: Effect of volume of n-hexane on the extraction of APSO

From the figure, the solvent volume of 150 ml gave the highest yield of 6.62 g APSO and at higher value of solvent volume; the yield of the oil decreases with numerical values of 5.79 and 5.76 g obtained using n-hexane volumes of 200 and 250 ml respectively. At lower volume of 100 ml, the amount of solvent available could not maximize the amount of oil extracted. Higher volume of solvent above 150 ml took longer time before they start boiling thereby reducing the number of reflux under gone by the solvent which subsequently leads to reduction of oil yield.

3.3 Effect of Extraction Time on the Yield
of Oil from African Pear Seed

The effect of extraction time was put into test so as to know the maximum time required to extract oil from the Africa pear seed oil. Figure 4.3 revealed the results of such test and from the result it was evident that the oil yield increases with time and that the maximum time of 60 minutes is required for the extraction of the APSO with a yield of 6.4 g.

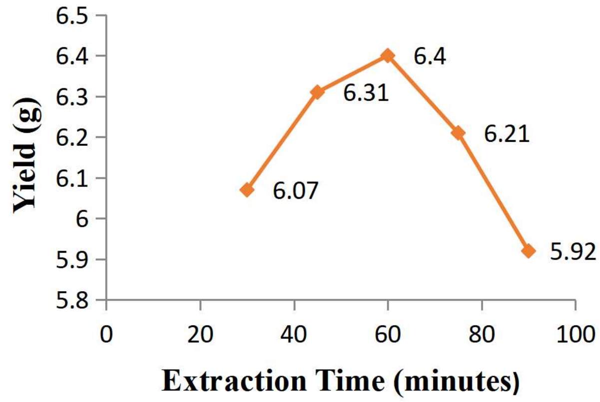

Table 3: Effect of extraction time on the extraction of APSO

At the extraction time of above 60 minutes and temperature of 80 ^{O}C above the boiling point of n-hexane more solvent escapes from the condenser thereby reducing the amount of available solvent to extract the oil. This is the reason why the yield of oil reduces to 6.21 and 5.92 g for the extraction time of 75 and 90 minutes respectively.

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3.4 Response Surface Methodology
(RSM) Optimization of Oil Extraction
from Africa Pear Seed

Using the results from the preliminary investigations of the extraction process parameters the three factors investigated and their levels that is lower, midpoint and higher levels is showed in Table 4.1

Table 1: Factors and their levels for Box-Behnken Design

Variable	Symbol	Coded factors level		
		-1	0	+1
Temperature (^{O}C)	A	60	70	80
Volume (ml)	B	100	125	150
Time(min)	C	30	45	60

I Design of Experiment for oil
Extraction from Africa Pear Seed

The inputted coded factors in Table 1 suggested seventeen experimental runs by design expert 13 software using Box-Behnken RSM Design. The From the table, the coded factor levels for the temperature are 60, 70 and 80 ^{O} C for the lower, midpoint and the higher levels while that of the solvent volume and the extraction time are; 100, 125 and 150 ml; 30, 45 and 60 minutes for the lower, midpoint and the higher respectively. Results of these experimental runs carried out as suggested by the software were revealed in Table 2.

Table 2: Experimental yields for Box-Behnken experimental design of APSO extraction

Std	**Run**	**Temp (A) ^{O}C**	**Volume of n-Hex (B) ml**	**Time (C) min**	**Yield (g)**
14	1	70	125	45	4.25
12	2	70	150	60	6.24
13	3	70	125	45	4.24
7	4	60	125	60	5.64
17	5	70	125	45	4.23
15	6	70	125	45	4.44
6	7	80	125	30	5.89
11	8	70	100	60	6.02
1	9	60	100	45	5.29
4	10	80	150	45	6.33
16	11	70	125	45	4.21
9	12	70	100	30	5.01
8	13	80	125	60	5.99
2	14	80	100	45	5.76
10	15	70	150	30	5.12
5	16	60	125	30	3.90
3	17	60	150	45	5.31

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From the table, it was observed that the lowest experimental yield was recorded at the run sixteenth (16) with a numerical value of 3.90 g oil yield obtained at temperature of 60 ^{O} C, Solvent volume of 125 ml and extraction time of 30 minutes while the highest yield of 6.33 g was recorded at higher values of the coded factors that is at temperature of 80 ^{O} C, solvent volume of 150 ml and extraction time of 60 minutes. Comparing the results of the lower and the higher yield it is evident that all the coded factors has a positive effect of the yield since all increase in the three, results in an increase in the yield.

When the results of the yields obtained for the experimental design was run with the design expert software, the fit summary Table 3 was generated and the fitted model is a quadratic model

Table 3: Fit summary model for optimization of extraction of APSO

Source	Seq. P-val	Lack of fit P-val	Adjusted R^2	Predicted R^2	Recom
Linear	0.1057	0.0003	0.2190	0.0359	
2F1	0.7462	0.0002	0.0917	-0.3857	
Quadratic	<0.0001	0.1023	0.9691	0.8314	suggested
Cubic	0.1023		0.9868		Aliased

The quadratic model was suggested with a sequential P-value of < 0.0001, lack of fit P-value of 0.1023, adjusted and predicted R^2 of 0.9691 and 0.8314 respectively.

The analysis of variance (ANOVA) was also generated and the result is revealed in Table 4. From the results, the suggested model F- value of 56.76 implies that the model is significant as there is only 0.01 % chance that F-value as large as this will occur due to disturbance. The model terms with P-values less than 0.0500 indicate that those model terms are significant while those with P-values greater than 0.1000 are not significant model terms. In that regard, A, C, AC, A^2, B^2 and C^2 are the significant model terms and on the other hand, B, AB and BC are the insignificant model terms.

Table 4: Analysis of variance (ANOVA) for the extraction of APSO

Source	Mean square	F value	P value	Comment
Model	1.17	56.76	<0.0001	Significant
A-Temp	1.83	88.77	<0.0001	
B-Volume	0.1058	5.12	0.0581	
C-Time	1.97	95.38	<0.0001	
AB	0.0756	3.66	0.0973	
AC	0.6724	32.55	0.0007	
BC	0.0030	0.1464	0.7133	
A^2	1.41	68.10	<0.0001	
B^2	2.83	137.23	<0.0001	
C^2	1.07	51.57	0.0002	
Residual	0.0207			
Lack of fit	0.0364	4.13	0.1023	Not Significant
Pure error	0.0088			
Correlation total				

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The lack of fit F-value of 4.13 is not significant and therefore suggests that the model well fitted the experimental results. This F-value of 4.13 indicates that there is only 10.23 % chance that this value could occur due to disturbance. The result for the model fit statistics is presented in Table 5.

Table 5: Model Fit statistics for the extraction of APSO

Standard deviation	0.1437
Mean	5.17
Coefficient of variance	2.78
R^2	0.9865
Adjusted R^2	0.9691
Predicted R^2	0.8314
Adequate precision	22.0787

From the result, the predicted R^2 of 0.8314 is in agreement with the adjusted R^2 value of 0.9691 since the difference between the two is less than the maximum allowable threshold value of 0.2. The adequate precision which is a measure of signal to disturbance ratio, suggests that the ratio should not be less than 4. The ratio of 22.079 indicates an adequate signal or precision.

The R^2 value of 0.9865 from this particular research is greater than the value of 0.8454 reported by Adepoju *et al*., (2019) for the same Africa pear seed oil using Box-Behnken RSM Design. When the fit statistics was also compared with that of the work reported by Musa *et al*., (2016) using central composite RSM design for the extraction of Avocado pear seed oil the standard deviation of 0.1437 from this particular research is better than the value of 1.12 reported by Musa *et al*., (2016). The R^2 value of 0.9865 from this research is in closer agreement with 0.9211 reported by Musa *et al*., (2016) while the adjusted R^2 of 0.9691 and the adequate precision of 22.0787 recorded from this work are better than the values of 0.8648 and 13.016 respectively reported by Musa *et al*., (2016).

I The Model equation

The equation suggested by the software in terms of the coded factors is presented as equation (1)

$$\text{Yield (Y)} = +4.27 + 0.4788A + 0.115B + 0.4963C +$$

$$1375AB - 4100AC + 0.0275BC + 0.5780A^2 + 0.8205B^2 + 0.5030C^2 \text{ ……… (1)}$$

From the ANOVA Table 4, the significant model terms are A, C, AC, A^2, B^2 and C^2. In this regard eliminating the insignificant model terms which are: B, AB and BC, the final model equation for the optimum yield of APSO (*Decryodes edulis*) is given by final equation (2)

$$\text{Yield (Y)} = +4.27 + 0.4788A + 0.4963C - 4100AC + 0.5780A^2 + 0.8205B^2 + 0.5030C^2 \text{ ... (2)}$$

The final equation 2 can be used to predict response (yield) of any given level of each factor in the equation and as such, the equation can be extremely useful for identifying the relative impact of the factors by comparing the factor coefficients.

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When then the predicted oil yield was plotted against the actual experimental yield, the graph in Figure 4 was obtained. The plot of this nature is usually carried out to see whether the points fall along a straight line in other to come into conclusion that the residuals follow a normal distribution (Umeuzuegbu*, et al.*, 2020).

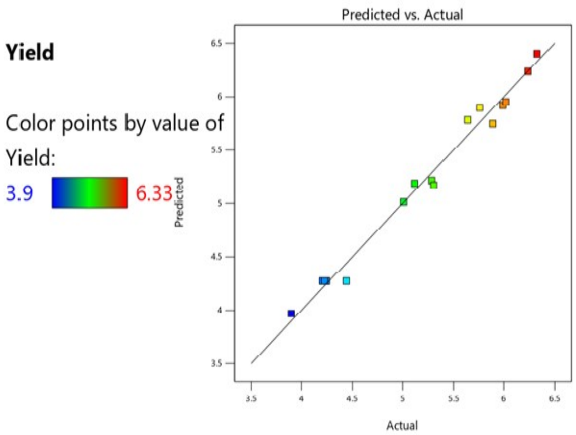

Figure 4: Plot of predicted against actual yield of APSO

The points in Figure 4 were closely distributed along the straight line of the plotted graph and this attest the good relationship between the experimental yields and the predicted yields. The plot also affirms that the selected model adequately predicted the response variables in the experimental values.

II Interactions of process variables

The interactions among the independent variables were represented by 3D response plots that explain the effects of combination of the variables on the yield of oil extracted from the Africa pear seed. Figure 5 shows the interaction between the temperature and the volume of the solvent and both factors has positive effect on the oil yield.

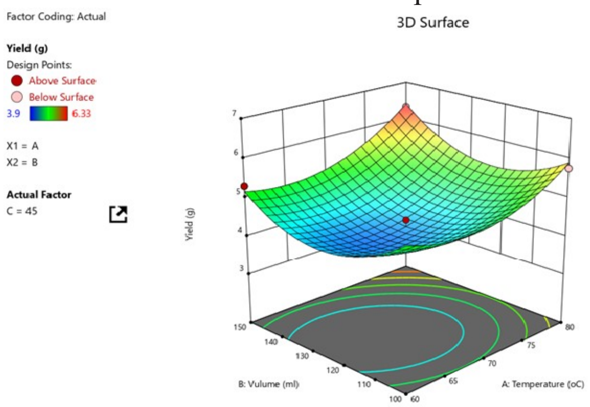

Figure 5: Response surface plot for the interaction between temperature and volume of solvent

The lowest yield recorded by their interaction is 4.44 g oil at a temperature of 70 ^{O} C and solvent volume of 125 ml while the extreme yield of 6.33 g at the highest peak of both the temperature and solvent volume with numerical values of 80 ^{O} C and 150 ml.

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Figure 6 shows the interaction between the temperature and time of extraction. The interaction between the temperature and the extraction time follows the same trend of positive impact on the yield when both are increased simultaneously.

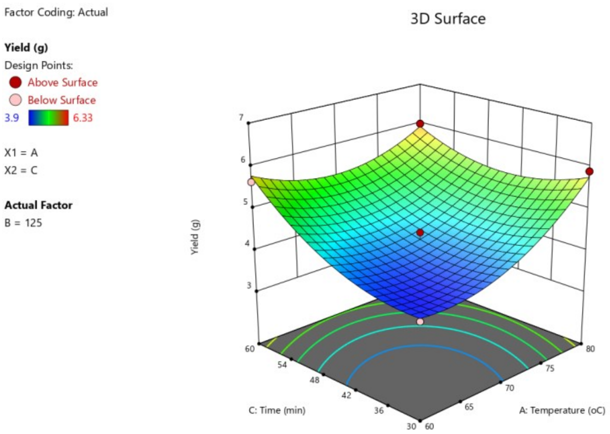

Figure 6: Response surface plot for the interaction between temperature and extraction time

The lowest yield of their interaction at a temperature of 60 ^{O} C and extraction of 30 minutes with a numerical value of 3.90 g oil yield which is the lowest recorded in the research while the highest yield of their interaction is 5.99 g at a temperature of 80 ^{O} C and extraction of 60minutes.

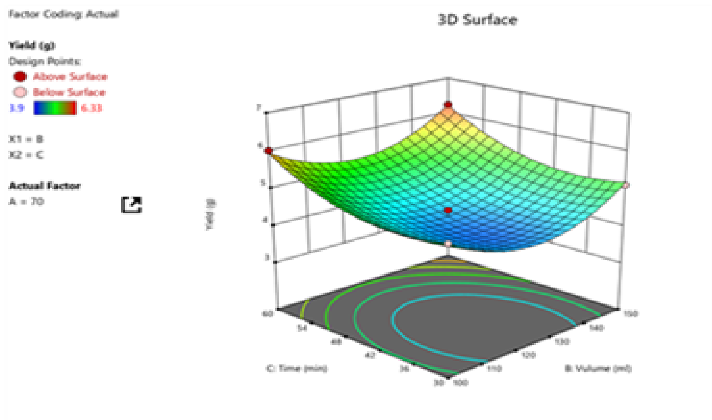

Figure 7: Response surface plot for the interaction between solvent volume and extraction time

The interaction between the extraction time and solvent volume is well described by Figure 7. From the figure, increase in both result in increase in yield of oil. The extraction time of 45 minutes and solvent volume of 125 ml recorded the lowest oil yield of 4.44 g and at the highest level of their interaction at an extraction time of 60 minutes and solvent volume of 150 ml, the highest yield of 6.12 g was obtained.

II Optimum conditions for the extraction of APSO

The optimum conditions suggested for the maximization of the yield of oil from Africa pear seed oil are temperature of 80 ^{O} C, volume of n-hexane of 150 ml and 60 minutes extraction time. The predicted oil yield under these conditions is 7.020 g.

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II Validation of APSO Model

For the validation of the model suggested, three set of experiments were carried out at the suggested optimum conditions and the average yield was calculated and compared with the predicted value via standard deviation. The results obtained are presented in Tables 6 and 7.

Table 6: Experimental average yield of APSO at optimum conditions

Run	APSO Yield (g)
1	6.85
2	7.12
3	6.91
Average yield	6.96

From Table 7 the yield of APSO for the three runs are 6.85, 7.12 and 6.91 g while the average yield was calculated to be 6.96 g

Table 7. Standard deviation for optimization of APSO extraction

Parameters	Temp (^{O}C)	Volume ofn-hex	Time (min)	Yield (g)
Optimization Value	80	150	60	7.02
Validation Value	80	150	60	6.96
	Standard deviation =			0.04243

The result of the predicted optimum yield was compared with the experimental average value and the standard deviation was calculated to be 0.04243 as showed in Table 4.8. This low value of the standard deviation further attests the accuracy of the model in predicting the actual experimental results.

3.5 Characterization of Africa Pear Seed Oil (APSO)

I Fourier Transform Infrared Spectrograph (FTIR)

The FTIR analysis was carried out on the APSO in order to determine the various functional groups present in the oil. The FTIR spectrum is presented in Figure 8.

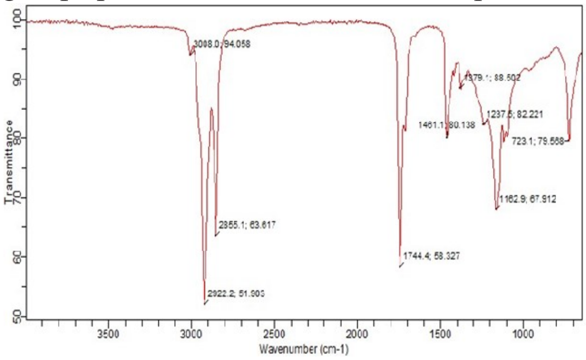

Figure 4.8: FTIR spectrum of Africa pear seed oil (APSO)

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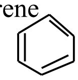
From Figure 8, it was depicted that a total of nine (9) absorption bands were identified which means that the oil is a complex organic compound (Asep and Rosid, 2019). The interpretation of the FTIR spectrum depicting the various vibrations and their corresponding functional groups is presented in Table 8.

Table 8: Interpretation of vibrations and functional groups in FTIR spectrum of APSO

S/No	Waveband (cm^{-1})	Vibration	Functional group
1	3008.0	Cis or Trans C-H stretch	Methyl($-CH_3$) from an alkene C=C
2	2855.1	Symmetrically C-H stretch	Methyl($-CH_3$) froma saturated compound
3	29022.2	Symmetrically C-H stretch	Methylene ($-CH_2$)From saturated compd
4	1481.1	C=C-C aromatic ring stretch	an Arene 
5	1744.4		-C(=O)OR (Ester)
6	1379.1	symmetrically C-H bend	-C(=O)OH Saturated (Carboxylic acid)
7	1237.5	aryl –O- stretch	Ether C-O-C
8	1162.9	Aromatic aryl –O- stretch	Ether C-O-C
9	723.1	Rocking	$-(CH_2)_n-$ from a saturated fatty acid

From the table considering the single bond region (4000-2500 cm^{-1}) of the spectra, three different peaks were identified. The first peak was at 3008.0 cm^{-1} which signify a Cis or Trans C-H stretch vibration from a methyl (CH_3) group from an Aliphatic saturated compound. This is followed by a peak at 2855.1 cm^{-1} indicating a methyl (CH_3) group with a symmetrically C-H stretch vibration while the last peak observed from the single bond region was detected at a wave band of 2922.2 cm^{-1} indicating the presence of a methylene (CH_2) group with a symmetrically C-H stretch vibration.

No peak was detected at the triple bond region (2500-2000 cm^{-1}) of the spectra and this signifies that no triple bond compounds are present in the oil complex molecule. Looking at the double bond region of wave band range of 2000-1500 cm^{-1} two peaks were identified one of which is at 1481.1 cm^{-1} signifying the presence of an Aromatic ring with a C=C-C aromatic ring stretch vibration. The remaining peak from this region was observed at a waveband of 1744.4 cm^{-1} signaling the presence of an Ester compound.

The finger print region has the highest number of peaks with a numerical value of four (4) peaks. The first was at a waveband of 1379.1 cm^{-1} indicating the presence of a methyl (CH_3) group with a symmetrically C-H bend vibration from a saturated fatty acid. At a wave band

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of 1237.5 cm $^{-1}$ an aryl –O- stretch vibration from an ether molecules is dictated while at a lower waveband of 1162.9 cm $^{-1}$ with an aromatic aryl –O- stretch vibration is noticed which is also from an ether compound. The last peak identified from this region was at a waveband of 723.1 cm $^{-1}$ which signifies the presence of a methylene $–(CH_2)_n-$ group with a rocking vibration from a saturated aliphatic compound.

I Fatty Acid Composition of APSO

The fatty acid composition of Africa pear seed oil was determined using Gas Chromatograph and Mass spectrograph (GCMS) and the result of the analysis is revealed in Table 9. Perusing the result of this analysis, it was found that the oil contains both saturated and unsaturated fatty acids with the unsaturated being predominant. Numerically the total unsaturated fatty acids amount to 59.6 % specifically comprising of mono-unsaturated Oleic acid with a composition of 38.86 % and di-unsaturated Linoleic acid with a fraction of 20.74 %.

Table 9: Fatty acids compositions of APSO

Component name	**Systematic name**	**Structural formula**	**Composition (%)**
Palmitic acid	Hexadecanoic acid	$CH_3(CH_2)_{14}COOH$	36.74
Stearic acid	Octadecanoic acid	$CH_3(CH_2)COOH$	3.66
Oleic acid	9-Octadecenoic acid	$C_9H_{18}=C_8H_{15}COOH$	38.86
Linoleic acid	9,12-Octadecadienoic acid	$C_6H_{12}=C_3H_4=C_7H_{14}$ COOH	20.74

The total composition of saturated fatty acids stands at 40.4 % with palmitic acid having the greater value of 36.74 % while stearic acid is the least with a composition of 3.66 %. The ratio of saturated and unsaturated fatty acids in this particular research is very much comparable with that reported by Ibanga *et al*., (2014) for the same type of oil seed with specific value of 52.38 % saturated fatty acids and 47.62 % unsaturated fatty acids.

Table 10 shows the comparison of the fatty acids composition of APSO obtained from this particular research with those obtained from other researches using same type of seed oil from different location and varieties and also different seed oils.

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Table 10: Literature comparison of Fatty acids compositions of APSO

	Fatty acid composition (%)						
Literature	Palmitic	Stearic	Oleic	Linoleic	Eicosenoic	Erusic	Linolenic
This research	36.74	3.66	38.86	20.74	-	-	-
Ogunsuyi & Oyeni (2018)	6.1	7.5	76.0	1.9	-	-	-
Esonye & Onukwali (2018)	10.65	12.54	53.13	-	4.71		
Ibanga *et al.*, (2014)	44.31	8.07	42.45	5.17	-	-	-
Abdelghani *et al.*, (2021)	11.2	8.5	65.9	-	-	-	-
Purendra, (2018)	1.802	0.669	9.53	14.51	6.976	48.586	11.986

The palmitic acid composition of 36.74 % from this research is comparable with the value of 44.31 % reported by Ibanga *et al*., (2014) for the same type of seed oil (APSO) while this value is far greater than the values of 6.1 % and 10.65 % reported by Ogunsuyi & Oyeni (2018) and Esonye & Onukwali (2018) for the same type of seed oil (APSO). When compared with researches using different seed oils, Abdelghani *et al*., (2021) reported lesser value of palmitic acid composition of 11.2 % from Jatropha Carcus seed oil while Purendra, (2018) reported the smaller palmitic acid composition of 1.802 % for Mustard seed oil.

Looking at the composition of stearic acid of 3.66 %, it can be compared to be of close range with 7.5 %, 8.05 % and 8.5 % reported by Ogunsuyi & Oyeni (2018), Ibanga *et al*., (2014) and Abdelghani *et al*., (2021) respectively since they fall within the same tens values.

The 38.86 % oleic acid from this research is close to the composition of 42.25 % reported by Ibanga *et al*., (2014) for the same seed oil but far less than 76.0 % and 53.13 % reported by Ogunsuyi and Oyeni (2018) and Esonye & Onukwali (2018) respectively for same type of seed oil (APSO). When compared with results of different seed oils, this value is also less than the value of 65.9 % reported by Abdelghani *et al*., (2021) for Jatropha seed oil and far greater than 9.53 % reported by Purendra, (2018) for Mustard seed oil. The total composition of 24.74 % linoneic acid recorded from this research is comparable with 14.51 % reported by Purendra (2018) and greater than 1.9 % and 5.17 % reported by Ogunsuyi and Oyeni (2018) and Ibanga *et al*., (2018) respectively. These similarities and differences in compositions of Africa pear seed oils may be attributed to different species of Africa pear (*Decryodes edulis*) used by different researchers, soil and climatic conditions and the level of maturity of the fruits (Ibanga *et al*., 2018).

I Physicochemical Properties of APSO

The results obtained from the analysis of physicochemical properties of APSO are presented in Table 11

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Table 11: Physicochemical properties of APSO

Property	Value	Property	Value
Yield (%)	46.4	Refractive index	1.336
pH	6.7	FFA (%)	4.443
Smoke point (^{O}C)	74	Acid value (mgKOH/g)	8.866
Fire point (^{O}C)	85	Saponification value (mgKOH/g)	213.18
Flash point (^{O}C)	95	Peroxide value (mgKOH/g)	25
Density (Kg/m^3)	0.8419	Viscosity (mPas)	3947.9
Specific gravity	0.8882		

From the Table, the percentage yield of APSO is calculated to be 46.4 % and the pH is 6.7. The density, specific gravity, refractive index, free fatty acid and viscosity are: 0.8419 Kg/m^3, 0.8882, 1.336, 4.443 % and 3947.9 mPas respectively. The Smoke point, Fire point and Flash point of the oil were 74, 85 and 95 ^{O}C respectively while the acid value, saponification value and peroxide value recorded are 8.886, 213.18 and 25 (mgKOH/g) respectively.

The results of the physicochemical properties of APSO obtained from this research were compared with some of the reports from related literatures and such comparison is presented in Table 12

Table 12: Literature comparison of physicochemical properties of APSO

Literature	This research	Ibanga *et al*.,(2014) (APPO)	Ogunsuyi & Oyeni (2018) (APSO)	Adepoju *et al*(2019) (APSO)	Chizoo *et al* (2019) (APSO)
Oil yield (%)	46.4	58.23	59.0	17.88	56.40
pH	5.7	-	4.39	-	-
Smoke point (^{O}C)	74	-	170	-	30
Fire point (^{O}C)	85	-	229	-	36
Flash point (^{O}C)	95	-	182	-	148
Density (g/ml)	0.8419	-	-	-	-
Specific gravity	0.8888	0.9000	0.8100	0.9217	0.8885
Refractive index	1.336	-	1.44	-	1.4269
FFA (%)	4.443	3.948	12.33	13.072	3.36
Acid value(mgKOH/g)	8.866	7.854	24.66	27..072	6.57
Saponification value (mgKOH/g)	231.18	227.21	171.10	129.03	249.82
Peroxide value (mgKOH/g)	25	-	45.2	37.60	1.88
Viscosity (Cst)	4.69	-	3.70	-	-

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From the Table, the yield of APSO from this research is 46.4 %. This value is less than the values of 58.23, 59.0 and 56.40 % reported by Ibanga *et al*.,(2014), Ogunsuyi & Oyeni (2018) and Chizoo *et al,* (2019) respectively but greater than 17.88 % reported by Adepoju *et al,* (2019). The value obtained falls within the range of 40-64 % yield of Africa pear oil extracted through solvent extraction method reported by Umoti and Okyi (1987). The pH value of 5.7 of acidic range is in agreement with 3.39 reported by Ogunsuyi & Oyeni (2018).The smoke point, fire point and flash points of 74, 85 and 95 ^{O}C are less than the values of 170, 229 and 182 ^{O}C respectively reported by Ogunsuyi & Oyeni (2018). When compared with the report of Chizoo *et al,* (2019), the smoke and fire points from this research are greater than the reported values of 30 and 36 ^{O}C respectively while the value of the flash point is less than 148 ^{O}C reported.

The specific gravity of 0.8888 recorded in this research, is in close agreement with the report of all researchers compared with in Table 12 while the refractive index of 1.336 is comparable and close to 1.44 and 1.42 reported by Ogunsuyi & Oyeni (2018) and Chizoo *et al,* (2019) respectively.
The low value of free fatty acid (FFA) of 4.44 % is close and comparable with the values of 3.948 and 3.36 % reported by Ibanga *et al*.,(2014) and Chizoo *et al,* (2019) respectively and less than the values of 12.33 and 13.072 % reported by Ogunsuyi & Oyeni (2018) and Adepoju *et al,* (2019) respectively.

When the acid value of 8.866 mgKOH/g was compared with the reports from other researchers, it was found that this value is comparable with the values of 7.854 and 6.57 mgKOH/g reported by Ibanga *et al*.,(2014) and Chizoo *et al,* (2019) respectively but less than 24.66 and 27.072 mg KOH/g registered by Ogunsuyi & Oyeni (2018) and Adepoju *et al,* (2019) respectively. In the case of the saponification value, this research identified a value of 231.18 mg KOH/g as against the lower values of 171.10 and 129.03 mg KOH/g reported by Ogunsuyi & Oyeni (2018) and Adepoju *et al,* (2019) respectively but lower than the value of 249.82 mg KOH/g registered by Chizoo *et al,* (2019). The value of the saponification value in question is in close agreement with 227.21 mg KOH/g reported by Ibanga *et al*.,(2014). The peroxide value of 25 meq O_2/g recorded from this research is less than 45.20 and 37.60 meq O_2/g recorded by by Ogunsuyi & Oyeni (2018) and Adepoju *et al,* (2019) respectively and greater than the value of 1.88 meq O_2/g registered by Chizoo *et al,* (2019). The viscosity of 4.69 Cst reported from this research is in close agreement with 3.70 Cst reported by Ogunsuyi & Oyeni (2018). These similarities and differences in physicochemical properties may also be due to the use of different varieties of Africa pear seed, different soil type and climatic conditions of the origin of the Africa pear tree (Ibanga *et al*., (2014).

4.0 CONCLUSIONS

The oil extraction from Batati African pear seed was successful optimized with optimum conditions of 80 ^{O}C temperatures, 150 ml volume of n-hexane and 60 minutes extraction time giving rise to an optimum yield of 46.4 %. The results of the characterization of the oil showed that it is comparable with the results reported by other researchers for the same APSO and some different oil seeds. From the results of the percentage yield and characterization of the oil, it can be suggested that it can used as a viable alternative feedstock for biodiesel manufacture.

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