Nigerian Journal of Engineering, Vol. 30, No. 2, August 2023, ISSN (print): 0794 – 4756, ISSN(online):2705-3954.

Nigerian Journal of Engineering,
Faculty of Engineering, Ahmadu Bello University, Zaria, Nigeria
journal homepage: www.njeabu.com.ng

Effect of Process Variables on the Oil Yield From *C.Albidum* using Response Surface Methodology

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Research Article

Abstract

Optimization of Chrysophyllum albidum seed oil extraction was carried out in this study. The study demonstrates the prediction capability of response surface methodology for oil extraction from Chrysophyllum albidum seed. RSM based on five levels, three factor central composite design was employed to obtain the best possible combinations of extraction temperature (50-60 °C), extraction time (3-6 hours) and solvent type (hexane and petroleum ether) for maximum oil recovery. A quadratic model was obtained and R^2, R, AAD and RMSE were determined to validate the model. The optimum conditions were found to be extraction temperature of 55 °C, extraction time of 6.62 hours with n-hexane a better solvent. For these conditions, oil yield of 12.70% was obtained which is in reasonable agreement with the predicted one. The values of R^2, R, AAD and RMSE were calculated as 0.9799, 0.9899, 0.016 and 0.12 respectively. Also the C. Albidum oil obtained was characterized to determine its physicochemical properties. The saponification value and iodine value of 191 and 30.94 respectively indicate that it is suitable for soap, cosmetics, candle and lubricating oil production. The FT-IR also reflects the presence of saturated and unsaturated compounds which makes the oil a potential for biodiesel production.

doi: 10.5455/nje.2023.30.02.08

Keywords

Albidum seed Oil; Central Composite Design; Solvent Extraction; Characterisation

Article History

Received: – January, 2023
Reviewed: – April, 2023
Accepted: – July, 2023
Published: – August, 2023

1. Introduction

Oil seed extraction is presently gaining significant attention worldwide. This is because of the inherent potentials of vegetable oils obtained from these seeds (Rajkumar and Sinha, 2011). The oil from these seeds has appreciable nutritional, pharmaceutical and industrial relevance, as it is used for cosmetics, drugs and feed formulation (Nimet *et al*., 2011), some can be modified to other value-added products (Akpan *et al*., 2006). Vegetable oil is also an important feedstock for bio-fuel production (Ajala and Adeleke, 2014). In recent times, there have been shortages of vegetable oil among developing countries of the world due to its applications and this has led to increase in importation to meet the ever growing demand of these products thereby placing heavy strain on foreign exchange of these developing nations. To overcome this challenge, novel oil bearing seeds need to be exploited (Musa *et al*., 2015). A number of these oil bearing seeds have been identified from less known crops. African star apple (*Chrysophyllum albidum*) is an example of less known plants that bear seeds containing oil. It is an economically important oil seed found in many part of tropical Africa. The plant belongs to the family of *Sapotaceae*. The fruit grows to maturity within the months of December to April. The fruit is commonly known as Cherry in English, Agbalumo in Yoruba, Udara in Igbo, Ububi in Idoma. The plant recently became a crop of commercial value in Nigeria because of recent discoveries. Although the oil yield is about 13 wt %, the seed has rarely been exploited for commercial purposes even when it is readily available as it is thrown away after consumption of the fresh and juicy pulp (Musa *et al*., 2015). Solvent extraction has been established widely for low oil bearing seeds due to its recovery ratio, as it leaves behind less than 1% oil (Ochigbo and Paiko, 2011). Solvent extraction is purely dependent on a number of variables such as solvent type, the extraction time, temperature of extraction, particle size (Sayyar *et al*., 2009). Extraction of oil from African star apple seeds has been reported by various authors. Amongst the few works are; extraction of *Chrysophyllum albidum*: optimization and characterization of oil extraction from *C. albidum* seed using 2^3factorial design (Musa *et al*., 2015). Ochigbo and Paiko (2011) reported the effect of solvent blending on the characteristics of oils extracted from the seeds of *C. albidum*. The extraction and characterization at 65°C for 3-4 hours was reported by Adebayo *et al*. (2012); the authors did not provide any explanation on the choice of process conditions. Sam *et al*. (2008) reported the extraction and classification of lipids from seeds of *Chrysophyllum albidum*. The work was limited to phytochemical screening and determination of fatty acid composition. Ajala and Adeleke (2014) reported the effect of drying temperature on the physicochemical properties and oil yield of African star apple. The authors limited the work to seed drying temperatures of 50, 60, 70, and 80 ºC.

As far as the authors' knowledge could go, there is no documented literature on the optimization of oil extraction from this seed using response surface methodology (RSM). RSM is a mathematical and statistical tool used for development of empirical models from experimental data. This tool requires minimum process knowledge which helps in saving time and cost of experiment. RSM is useful for quadratic approximation and has been explored more in optimization of vegetable oil for biodiesel production (Sarve *et al.,* 2015). RSM as a statistical tool has been applied to various investigations on extraction of seed oils from different oil bearing seed; examples includes: *Sesamuum indicum* (Betiku *et al.,* 2012), *Hibiscus sabdariffa* (Betiku and Adepoju, 2013), *Piper nigrum* (Bagheri *et al*., 2014), *Nitraria tangutorum* (Liu *et al.,* 2014), Lucky nut (Betiku and Adepoju, 2012), Bauhinia monandra seed oil (Akintunde *et al.,* 2015). This study therefore, investigates the effect of process variables: extraction temperature (ºC), extraction time (hours) and solvent type (n-hexane and petroleum ether) on solvent assisted extraction of oil from *chrysophyllum albidum* seed using central composite design.

2. Materials and Methods

2.1 Materials

The fruit of cherry (*chrysophyllum albidum*) were collected from a local market at Tunga in Minna, Niger state, Nigeria.

2.2 Methods

2.2.1 Feedstock preparation

The seeds of cherry were removed from the fruits, cleaned to remove the dirt and foreign materials present through hand picking, sun-dried for three days to reduce moisture content, de-shelled to remove the seeds by using a pestle, and grinded to the desired particle size with the aid of a mortar and pestle. Mesh size of 500 µm was used to screen the seed to the desired particle size.

2.2.2 Design of experiment and statistical analysis

A central composite design of RSM was used to verify the optimum conditions. This study consists of 26 runs ($2^k + 2k + m$), where k is the number of factors and m is the number of replicated centre points). Three variables were studied; the extraction temperature (A, 50-60 ºC), extraction time (B, 3-6 hours) and solvent type (C, n-hexane and petroleum ether) the particle size of *Chrysophyllum albidum* (500 µm), sample weight (10 g) and solvent volume (250 ml) were kept constant throughout the study. The regression coefficient and significant model term to fit the regression model and to determine the optimal factors level for maximum percentage oil yield of *Chrysophyllum albidum* were obtained. An empirical model was employed for a better understanding of the correlations between the factors and the yield (response) by using a quadratic model of a second-order polynomial as shown in Eq. 1:

$$Y = \beta o + \sum_{i=1}^{k} \beta i X i + \sum_{i=1}^{k} \beta ii X i^2 + \sum_{1 \le i \le j}^{k} \beta ij X i X j + e \quad (1)$$

Where Y is the predicted response variable, βo is intercept term, Xi and Xj are the coded independent variables, βij represent the coefficient of the interaction variables, and βii represent the coefficient of the quadratic variables.

2.2.3 Solvent extraction procedure

The solvent extraction of *Chrysophyllum albidum* was carried out using a 500 ml soxhlet extractor. Two hundred (250) ml of the respective solvents were poured into a round bottom flask. A prepared sample weight of 10 g of constant particle size (500µm) was placed in a thimble and inserted into the extractor. The soxhlet extractor was then heated to, and maintained at a temperature of 50 ºC. At this temperature, the solvent began to boil, and the vaporized solvent began to rise through the handle of the extractor into the condenser at the top. The condensed solvent dripped into the extractor containing the thimbles (solid sample to be extracted) and make contact with the sample containing the oil, leached through the pores, filled the siphon tube where it is refluxed back into the round bottom flask. The process continued until the desired extraction time of three hours was attained. The solvent was recovered by a rotary evaporator. The ratio of the difference between the weight of thimble before and after extraction to the weight before extraction was calculated to determine the percentage oil yield. It is mathematically expressed as Eq. 2.

$$Oil\ Yield\ (\%) = \frac{g1 - g2}{g1} \quad (2)$$

Where $g1$ is the weight of the sample before extraction and $g2$ is the weight of the sample after extraction.

2.2.4 Optimization and validation

The optimization process was carried out using central composite design (CCD) of RSM incorporated into the design expert software. The empirical result of the designed experiment was introduced into the software for analysis and thereafter generated a combination of actual and predicted result. The result was further subjected to optimization analysis using the same software with percentage yield of *Chrysophyllum albidum* as the objective function and the three process conditions as constraint with the prescribed limit. The optimization result obtained from the analysis was validated by repeating the experiment in the laboratory.

The responses predicted by RSM were compared with the observed response in order to evaluate the effectiveness of the optimization technique. The coefficient of correlation (R), coefficient of determination (R^2), absolute average deviation (AAD), and the relative mean square error (RMSE) were verified by equations (3-6) to check the best RSM model.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_{i,p} - Y_{i,e})^2}{\sum_{i=1}^{n}(Y_{i,p} - Y_e)^2} \quad (3)$$

$$AAD\ (\%) = \left(\frac{1}{n}\sum_{i=1}^{n}\left(\frac{Y_p - Y_e}{Y_e}\right)\right) \times 100 \quad (4)$$

$$R = \sqrt{R^2} \quad (5)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_{i,e} - Y_{i,p})^2}{n}} \quad (6)$$

Where $Y_{i,e}$ experimental data, $Y_{i,p}$ is the corresponding data predicted and n is number of the runs

2.2.5 Characterization of *Chrysophyllum albidum* seed oil

The physical and chemical properties of *Chrysophyllum albidum* seed oil sample were characterized. The saponification value, acid value, peroxide value, iodine value and specific gravity were analysed by standard methods of Association of Official Analytical Chemists (AOAC, 2000). The oil sample was further analysed using the ALPHA FT-IR spectrophotometer in the range of 4000-500cm^{-1}.

3.0 Results and Discussions

3.1 Modeling and variables optimization by RSM

The result of Central Composite Design of RSM in terms of real values and the responses in terms of oil yield is presented in Table 1. The maximum percentage oil yield of 12.70 (run 21) and 12.40 (run 8) using n-hexane and petroleum ether respectively were obtained. It is clear from the table that the process variables had effect on the percentage oil yield of *Chrysophyllum albidum* seed as different levels of study of the various process parameters (temperature, time and solvent type) gave different percentage oil yield. To establish the consistency of the prediction, the predicted values were plotted against the experimental values (Figure 1).

Table 1: 2^3 CCD design experimental results

Runs	CCD Component	(X_1) T (°C)	(X_2) I (h)	(X_3) S	Actual value	Predicted value
1	Factorial	50	3	S_1	9.7	9.48
2	"	60	3	S_1	9.91	9.88
3	"	50	6	S_1	11.42	11.48
4	"	60	6	S_1	11.83	12.09
5	Axial	47.93	4.5	S_1	10.15	10.35
6	"	62.07	4.5	S_1	11.14	11.07
7	"	55	2.38	S_1	9.02	9.26
8	"	55	6.62	S_1	12.4	12.24
9	Centre	55	4.5	S_1	10.6	10.54
10	"	55	4.5	S_1	10.7	10.54
11	"	55	4.5	S_1	10.5	10.54
12	"	55	4.5	S_1	10.58	10.54
13	"	55	4.5	S_1	10.6	10.54
14	Factorial	50	3	S_2	10.18	10.14
15	"	60	3	S_2	10.33	10.26
16	"	50	6	S_2	11.9	11.97
17	"	60	6	S_2	12.25	12.3
18	Axial	47.93	4.5	S_2	11.09	10.99
19	"	62.07	4.5	S_2	11.37	11.3
20	"	55	2.38	S_2	9.8	9.82
21	"	55	6.62	S_2	12.7	12.56
22	Centre	55	4.5	S_2	10.92	10.98
23	"	55	4.5	S_2	10.9	10.98
24	"	55	4.5	S_2	10.98	10.98
25	"	55	4.5	S_2	10.8	10.98
26	"	55	4.5	S_2	11.01	10.98

S_1 = petroleum ether, S_2 = n-Hexane

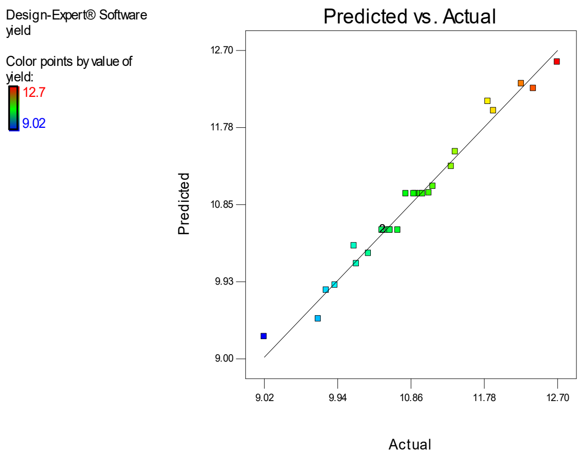

Figure 1: Predicted and experimental results of solvent extraction of *Chrysophyllum albidum* seed oil

Anova test was used to evaluate the statistical significance of the model equation and the results showed that the regression

Table 2: ANOVA for response surface quadratic model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob>F	
Model	18.5	8	2.31	104	<0.0001	significant
X_1	0.53	1	0.53	23.9	0	
X_2	16.3	1	16.3	734	<0.0001	
X_3	1.24	1	1.24	55.8	<0.0001	
X_1X_2	0.02	1	0.02	0.9	0.36	
X_1X_3	0.08	1	0.08	3.55	0.08	
X_2X_3	0.03	1	0.03	1.29	0.27	
X_1^2	0.1	1	0.1	4.47	0.05	
X_2^2	0.16	1	0.16	7	0.02	
Residual	0.38	17	0.02			
Lack of Fit	0.33	9	0.04	6.3	0.01	significant
Pure Error	0.05	8	0.01			
Cor Total	18.8	25				
R-Squared		0.98				
Adj R-Squared		0.97				
Pred R-squared		0.94				
Std Dev.		0.15				
Adeq Precision		37.5				

Non-significant effect (p>0.05)
Equations 8 & 9 are the model equations based on petroleum ether and n-hexane respectively as solvents.

is statistically significant at 95% confidence level i.e p<0.05 (Table 2). The model F-value of 103.64 and p<0.0001 for *Chrysophyllum albidum* seed oil extraction implied that the model was statistically significant. P<0.05 indicates that the model terms were significant and in this case X_1,X_2,X_3,X_1^2,and X_2^2 were all significant model terms. The fitness of the model, the regression equation and R^2 were evaluated. Fitting the data to various models (Linear, Quadratic and Cubic) and their subsequent analysis of variance shows that solvent extraction of *Chrysophyllum albidum* seed is most properly described with a quadratic polynomial model. The adjusted R^2 of the quadratic model (0.9799) was higher than that of linear (0.9611). The second order polynomial models used to express the oil recovery (Y) as a function of independent variables are shown in eq. 7 (in terms of coded and actual factors). The quadratic regression model based on the coded factors for oil yield estimated was developed for n-hexane (Eq. 7).

$$Y = 10.76 + 0.18x_1 + 1.01x_2 + 0.22x_3 + 0.050x_1x_2 - 0.070x_1x_3 - 0.042x_2x_3 + 0.085x_1^2 + 0.11x_2^2 \quad (7)$$

$$Y = 17.43980 - 0.35157x_1 - 0.08824x_2 + 6.66667e^{-003}x_1x_2 + 3.38250e^{-003}x_1^2 + 0.047028x_2^2 \quad (8)$$

$$Y = 19.67691 - 0.37968x_1 - 0.14482x_2 + 6.66667e^{-003}x_1x_2 + 3.38250e^{-003}x_1^2 + 0.047028x_2^2 \quad (9)$$

Where x_1, x_2 and x_3 are the values of the variables – temperature, time and solvent type respectively.

The developed RSM models estimation capabilities were evaluated. The closer the R^2 value to unity (1.0) the more accurate the model. The coefficient of determination R^2 of 0.9799 and the adjusted R^2 of 0.9705 are shown in the Table 2. The high values indicate the high level of significance of the model developed. AAD defines the degree to which the model prediction was accurate. The Adequate Precision of 37.528 indicates that the signal to noise ratio of the model is greater than 4. This shows that the model can be used to navigate the design space.
The response predicted by RSM were compared with the observed response in order to evaluate the effectiveness of this optimization technique. The coefficient of correlation (R), coefficient of determination (R^2), absolute average deviation (AAD), and the relative mean square error (RMSE) were used to validate the model developed. R shows the relationship between the predicted and experimental values while R^2 describes the extent of fit of the model. The closer the R^2 value to unity (1.0) the more accurate the model. The R value was 0.9899, showing that there is an excellent agreement between the predicted and actual values. The R^2 value of 0.9799 also suggests that the deviation of 97.99% for *Chrysophyllum albidum* seed oil extraction is ascribed to the process factors and only approximately 0.2% of this deviation is not described by this model (Ajala and Betiku, 2015). The adjusted R^2 (0.9705) was satisfactorily high enough to indicate the model significance. AAD defines the degree to which the model prediction was accurate. It has been suggested that for a good model fit, R^2 should be at least 80% (Ajala and Betiku, 2015). AAD and RMSE must be very

minute to signify a satisfactory model predictive ability. AAD and RMSE values in this study were obtained to be 0.016 and 0.12 respectively.

3.2 Effect of temperature (X_1 °C)

The results of both hexane and petroleum ether showed that oil yield increases with increase in temperature from 50 °C to 55 °C, and thereafter, any further increase resulted in a reduction in oil yield.. This is because at higher extraction temperatures, more solvent will become volatile leading to a high rate of diffusion of the solvent into the oil bearing seed matrix (Wang *et al*., 2022), but at higher temperature may lead to evaporation of the solvent, thereby reducing the among of solvent available for the extraction operation. The optimum oil yield were 12.40and 12.70% for petroleum ether and n-hexane respectively at a temperature of 55ºC . This result is in line with the report of Adebayo *et al*. (2012) and Ochigbo and paiko (2011). According to Mani *et al*. (2007) increasing temperature above the boiling point of solvents has negative effect on the oil yield

3.3 Effects of time (X_2 hr)

Time plays a very important role in the process of oil extraction from *C. albidum* seed. The extraction time was set at (3 – 6) hours. At time 6.62 hours, the maximum oil yield of 12.40% and 12.70% for both petroleum ether and n-hexane were observed. This indicates that increase in extraction time increases the contact between the solvent and the oil bearing seed which results to improve oil yield. Ayoola *et al*. (2014) reported that yield is time dependent. This is in line with the report of Musa *et al*. (2015). However there was no significant increase after 6.62 hours because the solvent density eventually reduced (Mani *et al*., 2007).

3.4 Effect of solvent type (X_3)

The role of solvent type in extraction processes is very important as it provides the medium through which oil can be dissolved. Several solvents are used for extraction processes but the one with the highest solvency power is more desirable. Therefore the effect of the various solvents were investigated. In this study, n-hexane and petroleum ether were used as solvent. The maximum yield obtained with n-hexane was found to be 12.70% while that of petroleum ether was 12.40%. The maximum oil recovery of hexane was found to be 0.3% higher than that of petroleum ether under similar conditions. This shows that among these two solvents, hexane was better.

3.5 Interactive effect of process variables

Interactive effects of time and temperature on oil yield for the extraction of oil from *C. albidum* seed using petroleum ether and n-hexane as solvents are respectively shown in Fig. 2a and 2b.

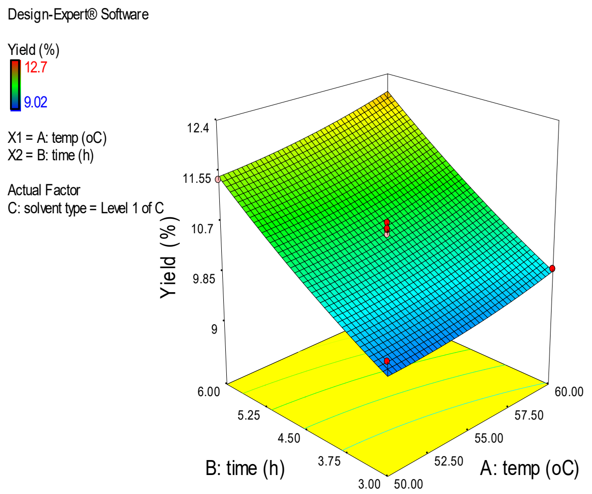

Figure 2a: Interactive effect of time and temperature on oil yield for the extraction of oil from *C. albidum* seed using petroleum ether as solvent.

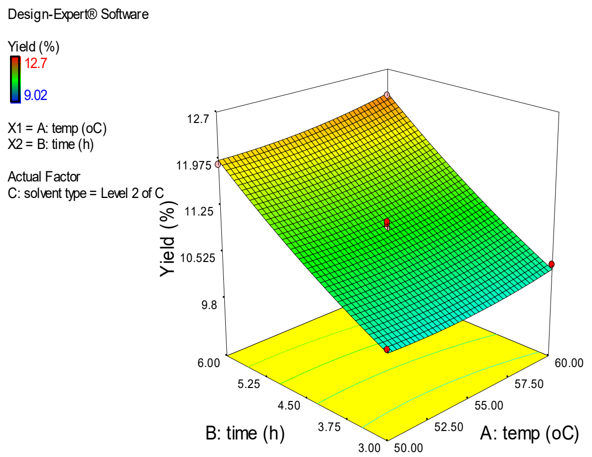

Figure 2b: Interactive effect of time and temperature on oil yield for the extraction of oil from *C. albidum* seed using n-hexane as solvent

Figure 2a shows the interactive effect between time and temperature on oil yield for extraction using petroleum ether as solvent. The extraction time and temperature are directly related to *Chrysophyllum albidium* seed oil yield. As the time and temperature increases, the oil yield increases. The effect of extraction temperature and time with n-hexane as solvent shown in Fig. 2b exhibited similar trend as that of petroleum ether. Although both n-hexane and petroleum ether exhibit the same pattern, extraction using n-hexane gave the highest positive effect on the oil yield with 12.70% as against 12.40% for petroleum ether. This may be due to the polarity index of n-hexane over petroleum ether (Akintunde *et al.,* 2015). According to Mani *et al.* (2007) as time and temperature of extraction increases, the density of the solvent with lower boiling point and polarity index reduces, leading to lower yield of extraction over time.

3.6 Physicochemical properties of *Chrysophyllum albidum* seed oil

The physicochemical analysis of *C. albidum* seed oil sample was performed using Association of Official Analytical Chemists (AOAC 2000) standard methods, the results of the analysis are presented in Table 3.

Table 3: Physicochemical properties of *Chrysophyllum albidun* seed oil

properties	Present study		Previous studies		
	P	H	1	2	3
Oil yield (%)	12.4	12.7	16.85	10.82	13.43
Colour	Dark brown	Dark brown	Dark brown	ND	Deep red
Density (g/ml)	0.879	0.874	ND	ND	ND
Specific gravity	0.879	0.874	ND	ND	0.89
Acid value (mgKOH/g)	5.049	4.769	2.52	2.81	4.5
Free fatty acid (%)	2.52	2.38	1.26	1.41	2.25
Saponification value (mgKOH/g)	196	191	228.4	248.8	199.5
Peroxide value(mg/kg)	1.75	1.5	1.48	ND	1.57
Iodine value	27.52	30.94	30	ND	35

P: Petroleum ether, H: N-Hexane; 1: Musa *et al.* (2015), 2: Ochigbo and Paiko(2011), 3: Adebayo *et al.* (2012)

The physicochemical analysis of the *Chrysophyllum albidun* seed oil is presented in Table 3. The oil extracted was dark brown in colour with a pleasant and sweet smelling odour. The oil yield of 12.40% and 12.70% was obtained using petroleum ether and n-hexane respectively; which are within the range of 10.82%, 13.43% and 16.85% reported by various authors as shown in Table 3 for the same seed. The difference in oil yield could be attributed to variation in species and gene; climatic and soil conditions, improper processing techniques such as prolong exposure of harvested seeds to sunlight which is capable of decreasing the oil yield considerably and the extraction process employed (Musa *et al.*, 2015).

3.6.1 Acid value

Acid value is a direct measure of the percentage content of free fatty acids in a given quantity of oil sample which describes the extent to which the triglycerides in the oil have been decomposed by lipase action into free fatty acids (Adebayo *et al.*, 2012). The acid value was determined to be 4.769, 5.049 with a corresponding FFA of 2.38, 2.52 for hexane and petroleum ether respectively, which was higher than the acid values of 2.52, 2.81, 4.5, 3.56 and their corresponding FFA of 1.26, 1.41, 2.25, 1.76 reported by authors indicated in Table 3. The difference observed could be attributed to geographical location, the age of the seed or storage conditions. Low acid values imply less fatty acid content, which indicates its edibility and less expose to the phenomenon of rancidification (Adebayo *et al*., 2012).

3.6.2 Saponification value

The saponification value of any oil is an indicator of fatty acid chain length (Dutta *et al.*, 2014). The saponification value of this cherry seed oil in this work using hexane and petroleum ether was 191 and 196 respectively. The result was within the range reported by the various authors in Table 3. This indicates high proportion of fatty acids of low molecular weight which in turn suggest that the oil has a potential for use in soap industries and for thermal stabilization of poly vinyl chloride (PVC). The saponification values were very close for both solvents used in this study; this shows that the physicochemical properties of oil are not affected by the solvent of extraction (Liauw *et al*., 2008).

3.6.3 Peroxide value

The peroxide value is a valuable measure of oil quality as it provides an indication of the stability of the oil. The peroxide values for the oil extracted in this work are 1.5 and 1.75 for hexane and petroleum ether respectively. This value is below the maximum acceptable value of 10 meq/KOH/g set by the Codex Alimentarius Commission. The values reported are very low and attest to the oxidative stability of the oil (Akbar *et al*., 2009). This further suggests the presence of high level of antioxidants in the oil (Kyari, 2008).

3.6.4 Iodine value

Iodine value is the measure of the degree of unsaturation of the oil (Nzikou *et al*., 2009). The unsaturation in the fatty acid chain is the main source of thermal instability and reason for causing carbon deposits due to burning (Dutta *et al*., 2014). The iodine value of 30.94 for hexane and 27.52 for petroleum ether in this study are comparable to the literature value (see Table 3). Vegetable oil with iodine value below 100 is usually classified as non drying oil. These classes of oil are usually suitable for the production of soaps, lubricating oils and lighting candles (Adebayo *et al.*, 2012). This is an attractive feedstock for this product because the oil has not been known commercially for consumption and can greatly help in minimizing the dependence on the use of known edible oils for making such products (Ochigbo and Paiko, 2011). The oil obtained can also be conveniently used for biodiesel production based on the low iodine value obtained.

3.7 FT-IR analysis

The FT-IR spectra of carbohydrates are typically used for the determination of their structural features by KBr pellets. The FT-IR spectrum for the cherry seed oil in this study is presented in Fig. 3. The functional groups identified from the FT-IR spectrum of the oil are shown in Table 4. It shows absorption band at 3452.70, 2906.82, 2061.97, 1718.63, 1654.98, 1440.87, 1143.83, 736.83, 592.17, 482.22 and 482.22cm^{-1}

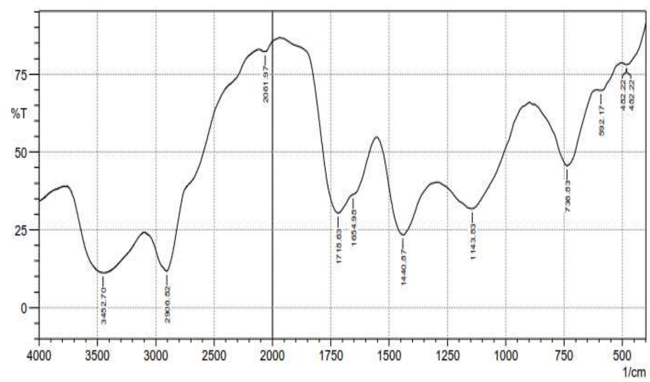

Figure 3: FT-IR Analysis of *Chrysophyllum albidum* seed oil

The specific intense peak at 3452.70 cm^{-1} and 2906.82 cm^{-1} were due to the O-H and C-H stretching vibration respectively (Du *et al*., 2014). The relative strong absorption peak at 1718.83cm^{-1} is demonstrated to be carboxylic group (C=O). The absorption band of 1654.98cm^{-1} shows symmetric stretch of unsaturated alkenes (C-C=C). The spectrum shows an absorption band at 1440.87cm^{-1} which indicates the presence of alkanes (H-C-H). The C-N is an indication of aliphatic amines present at the absorption band of 1143.83. Also the bands at 736.83 and 592.17cm^{-1} show both alkyl halides of C-Cl stretching and C-Br stretching respectively while the band at 482.22 reflects various inorganic compounds. The above descriptions of the functional groups of the various molecules found in the sample, shows the presence of saturated and unsaturated compounds which makes the sample a huge potential for biodiesel production.

4.0 Conclusion

Central composite design has successfully been used to establish the necessary conditions for maximum oil recovery from *C. albidum* seed via solvent extraction. The optimum yield of 12.7% was obtained at extraction temperature of 55 ºC, extraction time of 6.62 hours with n-hexane as solvent as against 12.40% at same extraction conditions with petroleum ether as solvent. The best RSM model that described the *C. albidum* seed oil extraction with a significant ($p<0.05$) is quadratic polynomial. The CCD generated quadratic model was well fitted. The physico-chemical properties of the oil show that it has a good prospect for industrial application such as production of soap, lubricants and cosmetics. It also has potential for biodiesel production. The FT-IR result shows that it contains both saturated and unsaturated hydrocarbon which makes it a huge potential for biodiesel production.

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Acknowledgement

The authors would like to thank the Department of Chemical Engineering, The Federal University of Technology, Minna, Niger State, Nigeria.