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OPTIMIZATION AND PHYSICOCHEMICAL ANALYSIS OF OIL EXTRACTED FROM DESERT DATE SEED

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Abstract
This study presents the investigation of the optimum operating conditions of temperature, time and solvent to biomass ratio on two responses (oil yield and solvent recovery) using n-hexane as the extraction solvent. 18 experimental runs were obtained using Central Design of Experiment, through which oil was extracted from pulverized desert date seed kernel using Soxhlet extraction technique. Optimization was carried out considering some factors; Temperature (50-70 ºC), time (1-4 hrs), and biomass/solvent ratio (7.5-15 mL/g) respectively. Afterwards, the obtained experimental runs data were fitted to a quadratic model and was analyzed statistically by Analysis of Variance (ANOVA). Physicochemical characterization and FTIR analysis of the oil was carried out. The results of the physicochemical analysis of the oil showed that Saponification value was 204.76 mg KOH/g, Iodine value of 76.14 mgL/g, Acid value of 2.2 mgL/g, Free fatty acid of 1.1 mgL/g, Relative density of 0.8225mg/ml, Specific gravity of 0.8410, Viscosity of 3.1mPas, Kinematic viscosity of 3.769cp and oil yield of 55.288%. FTIR results showed the presence of Aromatics (=C-H) and Aliphatics (C-H) functional group. Results showed that the model fits the analysis with p-values of 0.0013 and 0.0006 for the response on oil yield and solvent recovery respectively. However, it was observed that the effect of time and temperature was significant on both response on oil yield and solvent recovery. The optimum extraction yield of 55.29% was attained at optimum conditions of 67 ºC, 4.34 hrs and 13.37 (150 mL/11g) of temperature, time and biomass ratio respectively. The amount of oil extracted experimentally at these conditions was 53.83%.

***Keywords*: Bio-Oil, Desert-Date Seeds, Optimization, Physicochemical**

1.0 Introduction

Balanites aegyptiaca which is popular known as “Desert-date” in English and “Aduwa” in Hausa language [1-3]. Is a dicotyledonous flowering plant which belongs to the family of zygophyllaceae or the Balanitaceae [4, 5]. This tree is native to much of Africa and some few parts of the Middle East [6, 7]. It is a widely grown desert tree species with a strong tolerance to harsh conditions [8]. It has different parts consisting of varieties of bioactive substances with diverse medicinal properties [9]. However, the most valued important of the plant is the fruit which is categorized into four layers; outer skin layer (epicarp), fleshy pulp (mesocarp), hard seed shell (endocarp) and the inner part (kernel) [10]. The mesocarp is rich in carbohydrates and can serve as food, beverages and also has medicinal value [1, 11]. The endocarp can be used as solid bio-fuel source. The kernel contains high amount of oil but considered as non-edible due to the presence of toxic components like tannins, phytic and oxalate. Due to its unfavorable use for consumption it could serve as a good feedstock for various industrial uses [12].

Recently different research aims at the extraction and optimization of oil from different plants with high oil contents for the purpose of exploring its ultimate use and applications has emerge. The work of Chapagain, Yehoshua [4] investigated the suitability of desert date seed oil for large scale industrial production. Results of the oil extraction shows an oil yield of about 46.7% based on dry weight. Yusuff [13] investigated the combined and individual effects of particle size (0.6 mm to 1 mm), Temperature (50-70 ºC),

and solvent/biomass ratio (8:1-10:1 mL/g) on the yield of Jatropha Curcas seed oil with n-hexane as the extraction solvent. Optimization of the oil extraction process was carried out using Central Composite Design. Optimization results shows the optimum operating conditions of particle size, temperature and solvent/biomass ratio to achieve maximum oil yield of 56.69 wt% were 0.63 mm, 69.67 ºC and 9.98: 1 mL/g, respectively. Osman, Shigidi [14] carried out extraction and optimization of oil from *Sesame* seed. Oil extraction was carried out using n-hexane, chloroform and acetone as extraction solvents under various operating conditions. Optimization was done using Surface Response Methodology (RSM) to determine the oil yield. Results shows that n-hexane performed better in the oil yield obtained compared to chloroform and acetone. The developed model predicted that n-hexane having a rotational speed of 547 rpm with a contact time of 19.46 hours between the solvent and the seeds, and the solvent to biomass ratio of 4.93, gives the optimum oil yield of 37.03 %, outperforming chloroform and acetone which gives a predicted value of 4.75 % and 4.21 % respectively. While the optimum prediction yield of chloroform is 6.73 % at an operating condition of 602 rpm, 24 hours contact time and the solvent to biomass ratio of 1.74. on the other hand, the acetone predicted optimum yield was 4.37 % with operating conditions of 467rpm speed, 6 hours contact time and a solvent to biomass ratio of 1. It has been found that the maximum oil extraction yield from the chloroform is 6.73 % and acetone is 4.37 % which was much lower than that of n-hexane which is 37.03 %. Giwa, Kabir [15] investigated the optimum conditions of time, solvents to biomass ratio, particle size and temperature on n-hexane extraction efficiency measured in terms of oil extracted in gram. Oil was extracted from ground desert date seed kernel with the aid of Soxhlet apparatus in which 28 runs were obtained using D. Optimal Design of Response Surface Methodology. The temperature, time and solvent to biomass ratio were in the range of 50-70 ºC, 1-4 h and 10-20 ml/g respectively. At the end of the runs, the obtained experimental data were fitted to cubic model and statistical significance of the model was analyzed using Analysis of Variance (ANOVA). Result shows that the reduced cubic equation obtained was significant with p value of 0.001. And also, the significant term in the model were observed to be; time, solvent to biomass ratio and particle size, however the effect of temperature in the model was observed to be insignificant. The optimum operating conditions found was 60 ºC, 4 h, 15 (150 ml/10 g) and 0.6 mm. The maximum amount of oil extracted experimentally at these conditions was 6.08 g which conforms to the predicted value of 6.117 g. Kabo, Ali [5] worked on the extraction of oil from desert-date and analyzed the physicochemical properties of desert date seed oil. Soxhlet apparatus was used for the extraction and the oil was analyzed according to standard protocols. Results showed that desert date plant has high oil yield of 39.58 %, density 0.91g/cm^3, acid value of 2.66, iodine value of 98.74 g/100 g, saponification value of 186.5 mgKOH/g and low moisture content of 2.6% respectively.

2.0 Materials and Methods

Desert date fruit was purchased from Layin Mosko mini market Potiskum, located in Yobe State Nigeria. Since emphasize was only on the fruit seed kernel, the obtained desert date fruit were washed and soaked in water for 15 hours to remove the fruit from the seeds. The mesocarp covering the woody part of the seed, and the endocarp were properly stripped by hand and then the seed was further sun dried. Thereafter the seed coats (shell) were separated via decortication with a metal hammer. Afterward the kernel was isolated and pulverized using a blender to fine particle size prior to oil extraction. Plate 1 shows the desert date seed and seed kernel.

Plate 1: Desert date seed and seed kernel

2.1 Design of Experimental Runs and Optimization

Before the extraction of oil from desert date seed kernel was conducted, experimental design runs were generated to determine the optimal oil yield and solvent recovery using Design Expert 13. In this study, Response-surface methodology which is a statistical optimization tool that design experiment, analyze data and visualize results in order evaluate the different numerical factors considered was used. Soxhlet extraction technique was used in this study and the categorical factors considered in the extraction process to determine the response on oil yield and solvent recovery using n-hexane as the extraction solvent are shown in Table 1.

Table 1: Range of Experimental Factors Considered for Optimization of Oil Extraction

Factor	Symbol	Minimum	Maximum
Solvent/Biomass	A	7.5	15
Time	B	50	70
Temperature	C	1	4

A total of eighteen experimental runs were generated by Central Composite Design (CCD) of response surface methodology with the aid of Design expert 13 as shown in Table 4. According to the design matrix, a specified grams of fine powdered desert date kernel was wrapped in a pre-weighted filter paper and place in the extractor chamber of the Soxhlet apparatus. The extractor chamber coupled with a condenser is responsible in circulating cold water so as to prevent the escape of n-Hexane (solvent). 150 mL of Solvent was poured in a 250 mL round-bottom flask and attached to the siphon, and the entire system was placed on a digital heating mantle (ZNCL-TS500ML). After the extraction was complete, oil was recovered from the resulting mixture of oil and n-hexane by distillation. Then the weight of the extracted desert date oil for each experimental run was weighted and recorded in grams and the oil yield and solvent recovered was calculated as the weighted ratio of extracted oil and the powdered desert date seed.

2.1 Physicochemical and FTIR Analysis of Extracted Oil

The following physicochemical characteristics of the extracted desert date seed kernel oil were determined using standard ASTM and AOAC procedure.

2.1.1 Saponification Value

An American Standard for Testing Material (ASTM) method- D94 -07 (2017) was used for the determination of the Saponification Values of the samples. 2-5 g of the sample was weighed into the Erlenmeyer flask or conical flask. 25 ml of 0.5M ethanolic KOH was added and the resulting mixture was refluxed for 60 minutes. The resulting solution was subsequently titrated against 0.5 M HCl with phenolphthalein as indicator. The resulting end point was obtained when the pink color changed into colorless. The same procedure was used for the blank. The Saponification value (SV) was then calculated using the expression; Report the readings. The saponification value was calculated using equation 1.

$$SV = \frac{56.1\times(B-S)\times M\ of\ HCl}{Weight\ of\ sample} \quad (1)$$

Where B= volume in ml of HCl of used by blank.

S= volume in ml of HCl used by sample.

56.1= molar weight in mg of KOH equivalent to 1 cm^3 of 0.5M HCl.

M= Concentration in M of HCl used.

2.1.2 Acid Value

Acid values of the sample was also determined by ASTM method (ASTM – D 974(00). 0.2 – 0.5 g of sample was weighed into 250 ml conical flask. 50ml of neutralized ethyl alcohol was added. The mixture was heated on a water bath to dissolve the sample. The solution was titrated against 0.1 M KOH using phenolphthalein as indicator. The acid value was determined after which the free fatty acid was calculated respectively using equation 2;

$$AV\ (mg\frac{KOH}{g}oil) = \frac{56.1\times C\times V)}{Weight\ of\ oil\ sample\ in\ gram} \quad (2)$$

Where V= Volume of KOH in ml consumed by sample

C= Molar concentration of KOH

56.1= Molar mass of KOH

2.1.3 Free Fatty Acid

The free fatty acid (FFA) involves the quantification of the acidic components that are not bound to glycerol as triglycerides. It was determined using the Kirk, Sawyer [16] method where the acid value determination performed prior to FFA determination to ensure it is less than 1.0% from the relationship given by Norris (1965) in equation 3.

$$\% FFA = AV \times 0.5 \quad (3)$$

2.1.4 Iodine Value

This is a measure of the degree of unsaturation in any vegetable oil or animal fat. It is the weight of iodine absorbed by 100 parts by weight of the sample. It is expressed in (mg/g). The oil sample was poured into a dry glass- stopper bottle of about 250 ml capacity and a small rod was added. The weight (g) of the oil was gotten by dividing the highest expected iodine value by 20. 10 ml of carbon tetrachloride and 20ml of wiji's solution was added into the bottle and dissolved. The stopper which was moistened with potassium iodine solution was inserted and kept in the dark for 30 minutes. 15 ml of potassium iodide solution and 100 ml of water was mixed and titrated with 0.1 M of thiosulphate solution using starch as indicator just before the end point. A blank was carried out at the same time commencing with 10 ml of carbon tetrachloride.

$$Iodine\ Value = (V_1 - V_0) \times \frac{C \times 12.69}{MWeight\ of\ Ssample\ in\ grams} \quad (4)$$

Where C = is the concentration of sodium thiosulphate used.

V_1 = Volume of thiosulphate used for sample.

V_2 = Volume of thiosulphate used for blank

12,69= Constant.

2.1.5 Dynamic Viscosity

The relative density of oil, also known as specific gravity is a measure of how dense a particular type of oil is compared to the density of water. It was determined by ASTM method D – 129 –12b (2017). The sample was brought to a specified temperature and a test portion was transferred to a hydrometer cylinder that had been brought to approximately the same temperature. The appropriate hydrometer, also at a similar temperature, was lowered into the test portion and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale reading and the temperature of the test portion were taken. The observed hydrometer reading was reduced to the reference temperature by means of a petroleum measurement table. Any hydrometer correction was applied to the observed reading and the corrected hydrometer scale reading recorded to the nearest 0.1 kg/m^3 as density.

$$Specific\ Gravity = \frac{Weight\ of\ 50ml\ of\ Oil}{Weight\ of\ 50ml\ of\ Oil} \quad (6)$$

$$Density\ (\frac{g}{l}) = \frac{Weight\ of\ 50ml\ of\ Oil}{Volume\ of\ 50ml\ of\ Oil} \quad (7)$$

3.0 Results and Discussions

3.1 Properties of Desert Date Oil

The properties of desert date oil are represented in Table 2.

Table 2: Physicochemical Properties of Desert Date Oil

Properties	Values
Saponification Value (mg KOH/g Oil)	204.76
Iodine Value (mg L/g Oil)	76.14
Acid Value (mg KOH/g Oil)	2.20
Free Fatty Acid	1.10
Relative Density (mg/ml)	0.8225
Specific Gravity	0.8410
Viscosity (mPas)	3.10
Kinematic Viscosity (cp)	3.769
pH	

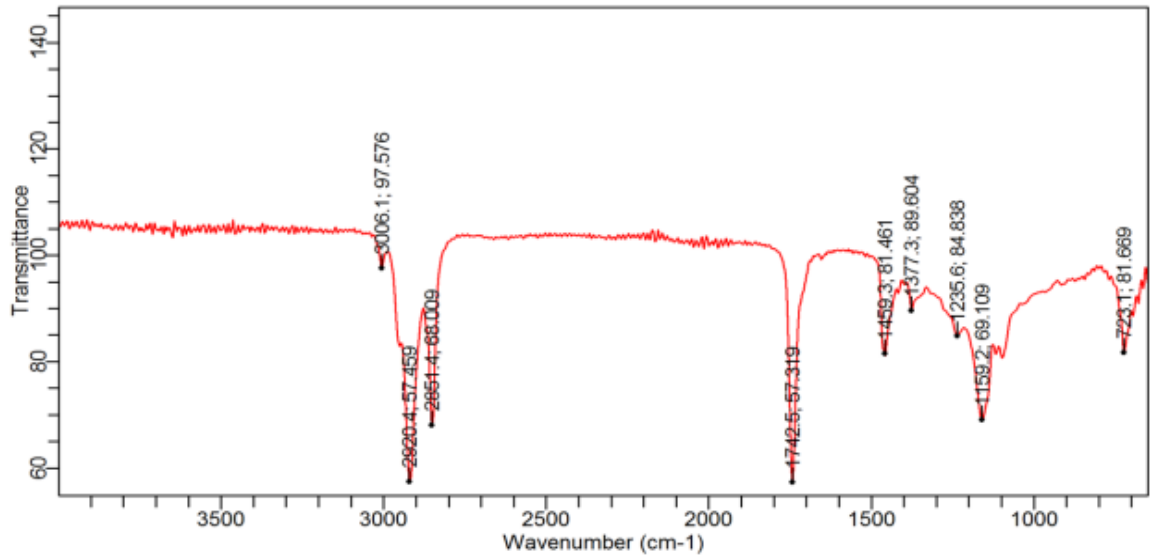

Figure 1: FTIR Spectrum of Desert Date Oil

3.1 FTIR Analysis of Desert Date Oil

Figure 1 shows the IR spectrum of desert date oil. The corresponding variation peaks for the functional groups are represented in Table 3.

Table 3: Characteristic functional groups present in Desert Date oil

Peak	Type of Vibration	Functional Group	Wave Number cm^{-1}
1	(=C–H) stretching	Olefin and aromatics	3006.1
2	(C–H) Asymmetric Stretching	Aliphatics	2920.4
3	(C–H) Symmetric Stretching	Aliphatics	2854.4
4	(C=O) stretching	Esters and ketones	1742.5
5	(C–H) bending vibration in methylene	Alkene	1459.3
6	Asymmetric C–O Stretching in C–C(=O)–O bonds	Ester	1377.3
7	Asymmetric C–O Stretching in C–C(=O)–O bonds	Ester	1235.6
8	Asymmetric C–O Stretching in O–C–C bonds	Ester	1159.2
9	C–H rocking-bending vibration	Alkane	723.1

3.1 Result of Oil Optimization

Table 4 illustrates the oil extraction experimental runs carried out. The variations of the experimental factors based on the design matrix corresponded to different yield of desert date oil, which signifies that the extraction of oil from desert date seed using n-hexane as the extraction solvent was affected by different operating conditions considered. The maximum amount of oil yield of 54.37 % (54.37 g) was achieved at 71.89 ºC, 3.345 hours, 150 ml:11.12 g, and 84.13 % of temperature, extraction time, solvent to biomass ratio and solvent recovery respectively. In like manner, the minimum yield of 10.6 was obtained at 40 ºC, 2.5 hrs, 150 ml:13.33g, and 89.40 %. Particle size was considered to be fine powder. The results showed the effect of the variation in time, temperature and amount of biomass on the effectiveness of the oil yield with respect to the extraction process with considerations to fine particle size. The various effects of each of these factors on the extraction can be further explain based on the fact that decrease in biomass ratio can expose the surface and can aid the availability of more solvents for mass transfer [15]. In addition, an increase in extraction time also provides more room for mass transfer to take place until all the oil is extracted. Also, increase in solubility of the solute (oil in biomass) is caused by higher kinetic energy attained at high temperature by the solvent molecules, which is responsible for breaking down of the bond holding the solute together in the biomass structure.

Table 4: CCD Experimental Result Matrix

Run No	A (mL/g)	B (hours)	C (°C)	Solvent Recovery (mL)	Solvent Recovery (%)	Oil Yield (g)	Oil Yield (%)
1	11.25	4.00	60.00	11.92	79.47	5.19	51.90
2	9.02	3.39	48.11	12.80	85.33	4.71	47.09
3	11.25	2.50	40.00	13.41	89.40	1.06	10.60
4	13.48	3.39	71.89	12.62	84.13	5.44	54.37
5	11.25	2.50	60.00	12.14	80.93	4.67	46.65
6	9.02	1.61	71.89	12.25	84.47	5.11	51.11
7	13.48	1.61	48.11	12.07	89.07	4.33	43.32
8	13.48	3.39	48.11	13.36	82.53	4.78	47.81
9	9.02	3.39	71.89	12.38	82.87	5.25	52.50
10	11.25	1.00	60.00	12.43	89.53	4.70	46.95
11	15.00	2.50	60.00	13.43	87.33	5.24	52.40
12	9.02	1.60	48.11	13.10	90.67	4.13	41.31
13	13.48	1.60	71.89	12.06	85.33	5.17	51.67
14	7.50	2.50	60.00	13.60	82.67	5.09	50.90
15	11.25	2.50	60.00	12.80	80.27	4.64	46.35
16	11.25	2.50	60.00	12.40	80.60	4.67	46.65
17	11.25	2.50	80.00	12.04	80.00	4.79	47.85
18	11.25	2.50	60.00	12.09	80.40	4.66	46.50

The extraction data in Table 4 were fitted to a quadratic model. Other models were also considered; Reduced quartic model accounted for all the changes even at slight change in the independent variable with respect to response but could not give a clear value definition of the predicted press R^2 statistic. The Reduced cubic model fits the data with good interactions between variables (time/temperature and or solvent to biomass ratio) but nevertheless, gave a negative statistic of predicted R^2 value. Even though both models represent the system well (fit the analysis), The reasons for the choice of the quadratic model were due to the fact that the trial analyses performed with cubic and quartic model gave a less good result than the one done with the quadratic model. Equation 1 represent the resulting empirical model obtained for amount of oil in grams in actual terms;

$$Oil\ Yield = -28.53139 - 13.22100A - 11.90700B - 4.77256C + 0.598804DA^2 + 2.75263B^2 - 0.035011C^2 \quad \_\_ (1)$$

Table 5:Analysis of Variance for the Oil Yield Model (Response 1)

Source	Sum of Squares	Df	Mean Square	F-value	P-value
Model	1282.96	6	213.83	8.51	0.0013 significant
A-solvent/biomass	4.31	1	4.31	0.1718	0.6865
B-time	37.63	1	37.63	1.50	0.2465
C-Temperature	630.30	1	630.30	25.10	0.0004
A^2	112.12	1	112.12	4.46	0.0583
B^2	60.69	1	60.69	2.42	0.1483
C^2	310.10	1	310.10	12.35	0.0048
Residual	276.25	11	25.11		
Lack of Fit	276.19	8	34.52	1673.87	< 0.0001 significant
Pure Error	0.0619	3	0.0206		
Cor Total	1559.21	17			
Std. Dev.	5.01	R^2		0.8228	
Mean	46.44	Adjusted R^2		0.7262	
C.V. %	10.79	Predicted R^2		0.1854	
		Adeq. Precision		11.1342	

The results of analysis of variance for oil yield obtained for the model at biomass of fine particle size are given in Table 5. The p-value was significant however, when the P-values is less than 0.0500 it indicates that the model terms are significant. In this case B, C, A^2, B^2, C^2 are significant model terms, implying that variation of time and temperature significantly affected the extraction process. Also, the square

solvent/biomass ratio, square of time and the square of temperature had significant influence on the model. Values greater than 0.1000 indicate the model terms are not significant. The Model F-value of 11.85 implies the model is significant. There is only a 0.03% chance that an F-value this large could occur due to noise. The Lack of Fit F-value of 78.12 implies the Lack of Fit was significant because there is only a 0.01% chance that a Lack of Fit F-value this large could occur due to noise.

Also, the coefficient of variation (CV), which is the ratio of standard deviation to the mean, obtained for the model was 10.79% which is an acceptable CV value. The coefficient of determination R^2 obtained from the model was is 0.8228 which is close to 1 which signifies that the model is accurate and also mean that there is 82.28% certainty that the generated model can explain the variability of the data. The Predicted R^2 of 0.1854 is not as close to the Adjusted R^2 of 0.7262 as one might normally expect; i.e., the difference is more than 0.2. This may indicate a large block effect or a possible problem with the experimental data. Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 11.134 indicates an adequate signal

In conclusion, based on the statistical results of the three models considered, comparing the values of CV with the negative value of R^2 with respect to the adjusted R^2 value, the reduced quadratic model fits better though the reduced quartic model was not able to capture all the changes but it still shows that all the factors are significant. Modification was done on the cubic quadratic model to eliminate the aliased and some insignificant terms so as to improve the statistical significance. Equation 1 represent the empirical model obtained for amount in grams of oil in actual terms.

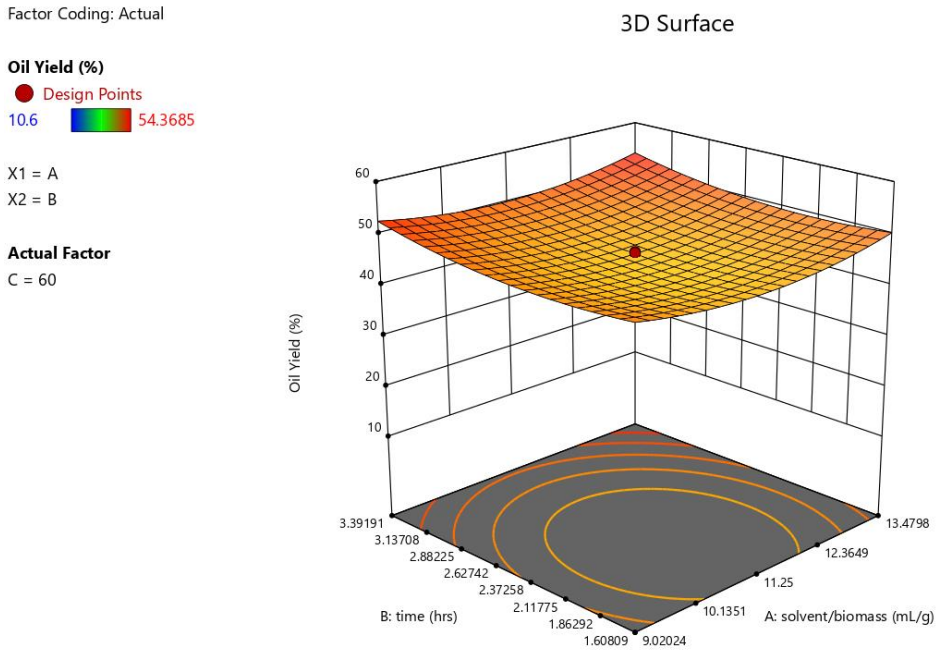

Figure 2: 3D Plots Showing the Effects of Solvent/Biomass Ratio and Reaction Time to Oil Yield

Figure 2 shows the 3D effect of solvent to biomass ratio and time on the oil yield at constant temperature. From the Figure, it was observed that an increase in reaction time and biomass ratio results to a spontaneous increase in oil yield at constant temperature. This means that increase in time gives more reaction time for oil extraction. Also, an increase in solvent/ratio provides more solvent for proper interaction with the pulverized desert date seed kernel.

3.1.1 Response 2 (Solvent Recovery)

Table 6 is the solvent recovery analysis of variance for reduced quadratic model. Equation (13) represent the reduced quadratic model equation in term of actual factors where A is the solvent/biomass ratio, B is the time and C is the temperature. The equation can be used to make predictions about the response for given levels of each factor and not to and should not be used to determine the relative impact of each factor. Here, the levels should be specified in the original units for each factor.

$$Solvent\ Recovery = -206.33907 - 7.48828A - 18.54905B - 1.77939BC + 0.106853C + 0.340959A^2 + 1.90877B^2 + 0.011237C^2 \quad \_\_(2)$$

Table 6: Analysis of Variance for the Solvent Recovery (Response 2)

Source	Sum of Squares	Df	Mean Square	F-value	P-value
Model	206.30	7	29.47	10.67	0.0006 significant
A-solvent/biomass	2.28	1	2.28	0.8259	0.3848
B-time	73.10	1	73.10	26.47	0.0004
C-Temperature	51.84	1	51.84	18.77	0.0015
BC	10.28	1	10.28	3.72	0.0826
A^2	36.35	1	36.35	13.16	0.0046
B^2	29.16	1	29.16	10.56	0.0087
C^2	31.94	1	31.94	11.57	0.0068
Residual	27.62	10	2.76		
Lack of Fit	27.37	7	3.92	46.51	< 0.0047 significant
Pure Error	0.2522	3	0.0841		
Cor Total	233.92	17			

Std. Dev.	1.66	R^2	0.8819
Mean	84.17	Adjusted R^2	0.7993
C.V. %	1.97	Predicted R^2	0.4598
		Adeq. Precision	9.5736

The Model F-value of 10.67 implies the model is significant. There is only a 0.06% chance that an F-value this large could occur due to noise**.** P-values less than 0.0500 indicate model terms are significant. In this case B, C, A^2, B^2, C^2 are significant model terms which signifies an increase or decrease of each of the factors can significantly affect solvent recovery. This result could contribute to the fact that, an increase in temperature and reaction time may eventually lead to evaporation of solvent used and indirectly affect the extraction process. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The Lack of Fit F-value of 46.51 implies the Lack of Fit is significant. There is only a 0.47% chance that a Lack of Fit F-value this large could occur due to noise. Significant lack of fit is bad -- we want the model to fit.

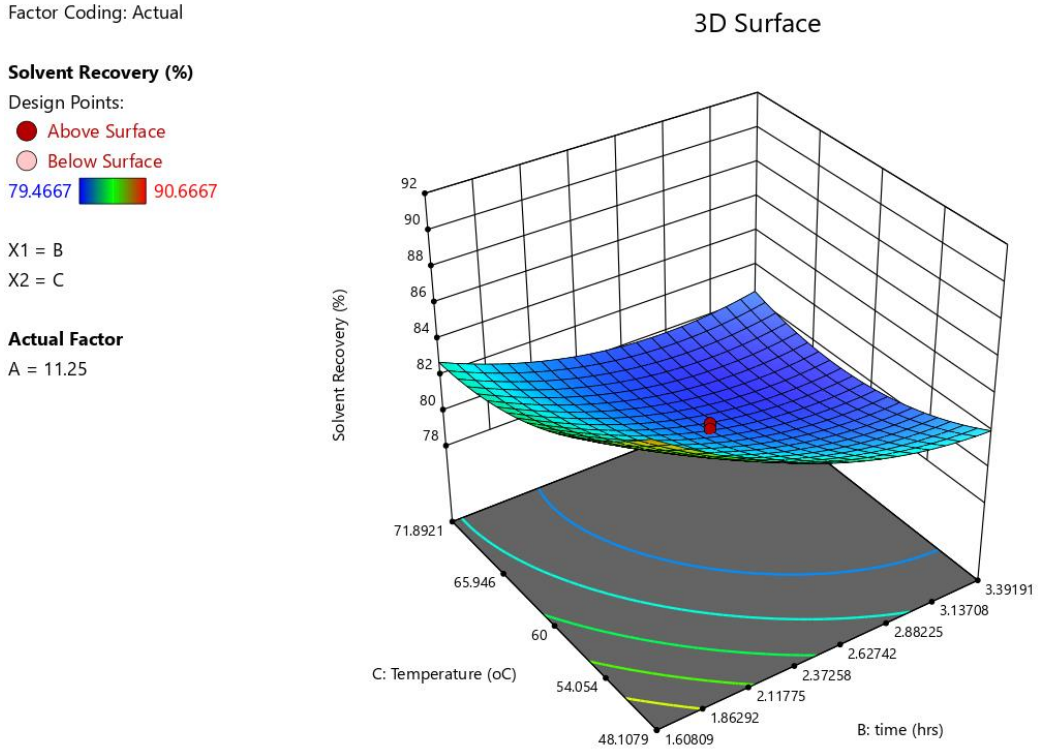

Figure 3: 3D Plots Showing the Effects of Temperature Ratio and Reaction Time to Solvent Recovery

Figure 2 shows the 3D effect of temperature and time on solvent (n-hexane) recovery at constant solvent/biomass ratio. As observed, an increase in temperature results to decrease in solvent recovery. Also,

an increase in reaction time results to a decrease in solvent recovery and can be related by the fact that an insignificant escape or loss of solvent during recovery becomes significant with increase in extraction time.

3.1.2 Percentage error analysis of optimization and validation data

The reduced quadratic model result of analysis shows optimum extraction yield of 55.288% is to be achieved at a given temperature of 66.694ºC, time: 3.345hrs and solvent to biomass ratio of 13.366 (solvent:150ml and biomass:11.22g). A 1 run experimental validation analysis was performed at the optimized conditions to determine the percentage error. Result shows that the errors are 2.633% and 1.495% for the bio-oil yield and the solvent (n-hexane) recovery respectively as shown in Table 5. The error is below the 5% acceptable error and therefore supported the claim that response surface quadratic model used is valid.

Table 7: Optimization and Validation of the Oil Yield

Experiment	**Operating Variables**			**Response**		**Error**	
	Solvent/Biomass (mL/g)	Time (hrs)	Temperature (ºC)	Bio-Oil Yield (%)	Solvent recovery (%)	Yield (%)	Recovery (%)
CCD (theoretical)	13.366	3.345	66.694	55.288	81.620		
Validation(actual)	13.366	3.345	66.694	53.832	80.400	**2.633**	**1.495**

Plate 2: Extracted Oil from Desert-Date Kernel Oil

Table 8: Summary of Extraction Results of Desert-Date Seed Kernel Reported Previously Compared to Present Study

Optimum Operating Conditions				
Solvent to Biomass Ratio ml: g	Time H	Temperature ºC	Oil Yield %	Reference
150:10	4.00	60.00	60.80	[15]
150:100	4.00	70.00	36.50	[17]
150:11	3.35	67.00	55.28	Present study

4.0 Conclusions

In this study, RSM was used to carry out optimization of desert date oil extraction. Result of the analysis of variance conducted on the developed quadratic model showed how well the model represented the extraction system using n-hexane as the extraction solvent with p-value of 0.0013 and 0.0006 on response 1 and response 2 respectively. The ANOVA results for oil yield showed that temperature significantly affected the process and ANOVA results for solvent recovery showed that time and temperature significantly affected the process. The optimum oil extraction conditions were found to be; 61.5 ºC, 3.4 hours and 150 mL/13.4g. the maximum oil yield and solvent recovery obtained at these conditions

experimentally were 53.8 % and 80.40 % respectively, which was close to the predicted value of 55.3 % and 81.62 % respectively.

Acknowledgement

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