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Research Article

Comparative Investigation of n-Hexane and Ethanol Solvents Used in *Eleais guinesis* Kernel Oil Extraction and Optimization via Two Computational Modelling

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ABSTRACT

The global usages of oil seed products are on high demand; which gave rise to the need to optimize the extraction of *Elaeis guinness* kernel oil. This work investigated the performance of n-hexane and ethanol as solvents for extraction and optimization of *Elaeis guinesis* kernel oil via Response System Methodology (RSM) and Artificial Neural Networks (ANNs) computational modeling. The 5 days sun-dried *Elaeis guinesis* Seeds collected were crushed, the oil was extracted from the powdered seed using a Soxhlet extractor, with n-hexane and ethanol as solvents. The result analyzed by average computation of 40min extraction time, 175 ml solvents, and 50g sample weight for both solvents shown that the average oil yield for n-hexane is 38.15% (w w^{-1}) and 28.83% (w w^{-1}) for ethanol. At the box-Behnken experimental design having the same averaged independent variables, the average predicted values of: RSM is 35.21; ANNs is 37.21 for n-hexane solvent, while for ethanol solvent, the average predicted values of: ANNs is 31.118; RSM is 30.80. The coefficients of determination (R^2) for RSM were 99.94% for n-hexane and 99.89% (w w^{-1}) for ethanol, and ANN has 99.99% (w w^{-1}) for n-hexane and 99.899% (w w^{-1}). As a result; n-hexane is better than ethanol in term of oil extraction, ANNs has higher predicted values for optimization in both solvents, therefore it is a better model for oil's optimization, it further proved that both models can be used adequately to represent the actual relationship of the chosen factors which can be applied for optimization simultaneously.

RESEARCH ARTICLE

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- *Elaeis guinesis* kernel oil,
- Box-Behnken,
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INTRODUCTION

The global utilization of oil is on increase and has led to increasing in demand for vegetable oil for both domestic and industrial use. In meeting this demand, oil is being extracted from the biological seeds like the groundnut, pawpaw, soya bean, and *Elaeis guinesis* seeds, which are vital in this regard due to the kind, volume, quality, and usefulness of oil derived from them. *Elaeis guinesis* (Oil palm) seed produces two major oils from the processing of Fresh Fruit Bunches (FFB) which are Crude Palm Oil and Crude Palm Kernel Oil (Otti *et al.*, 2014). The two kinds of oils produced are edible plant oils (Imoisi *et al.*, 2015), palm kernel oil is gotten from the kernel of the seed of oil palm (Poku, 2002). Elaeis guinesis kernel oil is used in manufacturing detergents, soaps, and as washing powders due to the lauric and myristic fatty acids present in it, it is used in the pharmaceutical industries, for the production of drugs for consumption purposes (Alander, 2004). According to Ijaola and Adepoju (2021b), *Elaeis guinesis* kernel oil is used as lubricants for steam engines, machinery, and as major raw material for soap manufacturing. Palm kernel oil is an excellent source of lauric acid, oleic acid, and myristic acid (Chandrasekharan *et al.*, 2000).

The quality of Elaeis guinesis kernel oil is determined by the physicochemical composition of the oil which is reported to contain highly saturated fatty acids which is semi-solid at room temperature, and several saturated and unsaturated fats in the forms of glyceryl laurate (Cottrell, 1991). It resists oxidative deterioration (Berger, 1992). This is recently corroborated by the discovery of Ijaola and Adepoju (2021b), who investigated the physicochemical properties of palm kernel oil and discovered that the physical state of the oil is yellowish-brown with the following chemical properties; FFA 11.08%, acid value 22.16 mg KOH g^{-1} oil, saponification value 140.123 mg KOH g^{-1} oil, iodine value 87.85 g l2 $100g^{-1}$ and higher heating value 30.51, the finding which supports that the composition of the oil confirmed its impotence mentioned earlier.

Having established the quality of *Elaeis guinesis* kernel oil and its usefulness, the extraction of the oil is very crucial to making it available for consumption, hence the need to investigate the better solvent to be used in solvent extraction methods among other methods like mechanical screw-press, and traditional methods (Jin, 2008). The solvents that have been used for vegetable oil seeds solvent extraction includes; hexane, heptane, isohexane, isopropanol, and ethanol (Connerton *et al.*, 1995; Baker and Sullivan, 1983, Senior *et al.*, 1998). These have been investigated on cottonseed (Abraham *et al.*, 1988), sunflower seed (Senior *et al.*, 1998) and soybean (Baker and Sullivan, 1983) and found to be appropriate as solvents in extraction. This work investigates and compares two solvents namely n-hexane and ethanol as a solvent for extraction of *Elaeis guinesis* kernel oil, having discovered the limitation of the hexane as it is identified to pollute the air when it is emitted during the oil extraction (Wan *et al.*, 1995a). For health and environmental safety, ethanol was researched as an adequate replacement for hexane to eliminate and or reduce the emissions of volatile organic compounds also potential traces of hexane in edible oils after extraction. Ethanol is reported to be non-toxic alcohol with fewer handling risks as compared to hexane in extraction (Suzana 2003; Ijaola and Adepoju, 2021b).

Because of the interest in extracting the optimum oil from the kernel; this work investigated the use of two computational models in optimizing oil extraction. Modeling is a scientific approach that represents ideas about the natural phenomenon under investigation, presenting alternatives to the real phenomenon, by referring to the existing knowledge (Gendy *et al.,* 2020). One of the generally used models is mathematical modeling (Najafi *et al.,* 2019). And the two mathematical models used to predict experimental behavior in this research are Response Surface Methodology (RSM) and Artificial Neural Networks (ANNs) which are significant in the field of processes in optimization (Gendy *et al.,* 2020). These methods determine the relationship between the input and output variables through the data derived from the experiment. The models are used for the prediction of the optimum situations of independent variables (Ahmadpour *et al.,* 2018). RSM enables the estimation of desired responses from several independent variables with relationships between them. The major benefit of RSM is fewer experimental runs are sufficient to provide a statistically significant result, and because it has provided efficient solutions, it successfully used in engineering problems (Osman *et al.,* 2019; Selvan *et al.,* 2018). However, ANNs modeling is a statistical technique that solves problems that are not eligible for conventional statistical methods. It handles obscure, complex, incomplete problems; it is a model that produces predictions and generalizations at high speed (Gendy *et al.,* 2020).

Both RSM and ANN techniques do not need the precise expressions or the physical meaning of the system under investigation (Selvan *et al.,* 2018). Some existing scholars have compared the RSM and ANN in optimization like; Ahmadpour *et al.* (2018), discovered that the ANNs model is more accurate than the accuracy of RSM, Manda *et al.* (2019), showed that ANNs has better modeling accuracy than RSM, while Awolusi *et al.* (2019), stated RSM showed the supremacy over ANNs as a model that analyzes non-linear relationships of data sets, but ANNs provides good fitting for data and it is better for prediction. The findings from these scholars revealed that ANNs are better than RSM in optimization, though the cost of computation is high (Osman *et al.,* 2019). Since Ahmadpour *et al.,* 2018 employed caustic water waste for the comparison of the performance of the models, then, this work will study the performance of RSM and ANNs on optimization oil extraction, specifically the palm kernel oil.

The research work investigates the effectiveness of replacing hexane with ethanol as a solvent in extracting palm kernel oil by comparing the output of both solvents; it also seeks to find out which of the RSM and ANN perform better in optimizing the oil extracted through the two solvents considering the variable experimental inputs.

MATERIALS and METHODS

Palm kernel oil extraction and optimization from the seeds collected from the fields follow the methods described as follows:

Equipment and Reagent

The equipment that was used includes Muslim Bag, Soxhlet Extractor of 500 ml, Digital Weighing balance, Heating Mantle, Water Bath, and Oven. Flash Point Machine, Spectrometer as presented in figure 2 which is used to separate and measure the spectral component of the sample, Viscometer, Glassware which includes beakers, round bottom flask, conical flasks, pycnometer, Petri dish, Measuring cylinder and burettes. The analytical reagents used are; Ethanol, Potassium Iodide (KI), Phenolphthalein, Iodine, Chlorine, HCL, KOH, NaOH, and they are all obtained from BDH Chemical Ltd., Poole England (Ijaola and Adepoju, 2021b).

Seeds preparation

Palm kernel nuts were collected from Akwa Ibom State in July 2018, the nuts were cracked off the shells, and the broken shells were separated from the seed. Palm kernel seeds were sundried for two days and were later crushed and grounded.

Extraction Procedures

Four 500 ml Soxhlet extractors as seen in Figure 1, were used for this study alongside two solvents which are n-hexane, and ethanol. A known weight of palm kernel seed powder which ranged from 40-60 g was put in a Muslim bag and then placed in Soxhlet apparatus, and a known volume of the solvent ranging from 150-200 ml in a round bottom flask was placed on the heating mantle. The soxhlet apparatus was placed on the flask, the condenser is fixed and the water inlet and outlet are connected and with the aid of the resort, the stand was placed to balance. The water tap was turned on, the heating mantle was turned on and it provides heat at 68-70°C a temperature below the boiling point of the solvents. After the process, the solvents are recycled and the oil was left in the round bottom flask which is later weighed using a weighing balance. The oil yield was evaluated as the ratio of the weight of the extracted oil to the weight of palm kernel oilseed grounded sample as expressed in 3.1; oil obtained was stored in a freezer at 40°C for further characterization.

$$\%\,\text{Oil yield}\,(\text{w/w}) = \frac{\text{Weight of extracted oil in grams}}{\text{Weight of grinded samples in grams}} \times 100 \qquad (1)$$

Experimental Design

The experimental design used is Box-Behnken see Figure 3, employed by Ijaola and Adepoju (2021a), in the optimization of the extraction of oil from Moringa seed. Box-Behnken is a significant part of RSM in the design of experiments devised by George. E.P. Box and Donald Behnken in 1960 for three variable independent factors which coded as -1, 0, +1, design to fit quadratic model for the reasonable coefficient of the ratio of several experimental points (Karmoker *et al*., 2019). It is abbreviated as DoE, which is used for the model fitting of physical experiments, with numerical experiments. Its aim is the choice of the points where the response should be evaluated. The mathematical model of the process is needed for the optimal design of experiments; the model is usually polynomial with an unknown structure that is $y= f(xi)$ or $y= f(x_1, x_2, x_3)$, such that experiments are designed for the particular problem (Box and Draper, 1987). The research which is carried out in the year 2018; runs seventeen experiments with three independent variables which were: extraction time F_1 which ranged from 30-50 min, solvent volume F_2 which ranged 150-200 ml, and sample weight F_3 which ranged 40-60 g.

Figure 1. Three sets of the Soxhlet Extractor.

Figure 2. Spectrometer.

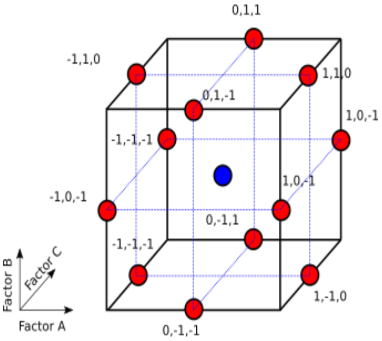

Figure 3. Box-Behnke extraction design.

RESULTS AND DISCUSSION

Extraction and Optimization of *Elaeis guinesis Ker*nel Oil Extraction

The extraction and optimization of *Elaeis guinesis* kernel oil, using n-hexane and ethanol in RSM and ANNs statistical computational models are employed, the experimental procedure valuation and determination of experimental results and values through design Expert Version 11.1.0.1 software for optimizing the extraction process. The formulas for the models are present as follows:

The experiment generated 17 experimental runs through a series of tests. The three variable independent factors employed were sample weight, solvent volume, and extraction time which are given in Table 1(a) and (b).

Table 1a. Independent variables and their levels for Box-Behnken design.

Variable	Symbol	Coded factor levels		
		-1	0	+1
Extraction time (min)	F_1	30	40	50
Solvent volume (ml)	F_2	150	175	200
Sample weight (g)	F_3	40	50	60

Table 1b. Box-Behnken experimental design for three independent variables.

Std run	F_1	F_2	F_3
1	30	150	50
2	50	150	50
3	30	200	50
4	50	200	50
5	30	175	40
6	50	175	40
7	30	175	60
8	50	175	60
9	40	150	60
10	40	200	40
11	40	150	40
12	40	200	60
13	40	175	60
14	40	175	50
15	40	175	50
16	40	175	50
17	40	175	50

Comparative Analysis of n-Hexane and Ethanol

A critical analysis of the values displayed in Table 2 (a) and (b) showed that the predicted values of *Elaeis guinesis* kernel oil yield for the two solvents were close to the experimented values obtained from the laboratory. In table 2a at 7th run (Std), with 175 ml of n-hexane, the highest yield of 37.60% (w w^{-1}) was recorded at values of 37.68 and 35.732 for RSM and ANN respectively, in contrast with the same 7th run-in Table 2b for the ethanol solvent of 175 ml the oil yield a lower of 26.63% (w w^{-1}) with 25.64 RSM predicted value which is lower to the predicted value of ANN at 29.581, at the same values for the remaining independent variables of 30 min extraction time and 60 g sample weight for both solvents. By average computation of 40 min extraction time 175 ml solvents (n-hexane and ethanol) and 50 g sample weight, the average *Elaeis guinesis* kernel oil yield for n-hexane is 38.15% (w w^{-1}) and 28.83% (w w^{-1}) oil yield for ethanol solvents. This shows that n-hexane is better in terms of oil extraction. However, Capello *et al.* (2007), opined that ethanol is better in terms of environmental health and renewability since ethanol is less toxic, and renewable.

Table 2a. Box-Behnken experimental design for three independent factors for n-hexane, oil yield, predicted, and residual values of RSM and ANN.

Std	**F_1**	**F_2**	**F_3**	**EKO Oil yield % (w w^{-1})**	**Predicted value (RSM)**	**Residue (RSM)**	**Predicted value (ANN)**	**Residue (ANN)**
1	30	150	50	30.92	30.88	0.0425	36.311	0.0011654
2	50	150	50	36.86	36.86	-0.0037	32.986	0.003548
3	30	200	50	35.97	35.92	0.0463	34.608	0.012062
4	50	200	50	35.72	35.76	-0.0350	35.968	0.0019233
5	30	175	40	31.56	31.52	0.0350	30.923	0.0032996
6	50	175	40	37.47	37.48	-0.0060	31.572	0.012094
7	30	175	60	37.60	37.68	0.0812	35.732	0.011577
8	50	175	60	37.47	37.48	-0.0060	33.079	0.00077682
9	40	150	40	33.08	34.91	-0.0425	33.068	0.0021047
10	40	200	40	36.31	33.12	-0.0463	34.845	0.0050696
11	40	150	60	34.84	36.36	-0.0812	37.693	0.012968
12	40	200	60	34.62	34.92	0.0038	36.865	0.0046598
13	40	175	50	33.07	34.58	0.0038	37.47	0.030336
14	40	175	50	37.47	33.07	-0.0060	37.47	0.00033598
15	40	175	50	37.47	37.48	-0.0240	37.47	0.00033598
16	40	175	50	37.50	37.48	0.0240	37.47	0.00033598
17	40	175	50	32.99	33.03	-0.0387	37.47	0.00033598

Table 2b. Box-Behnken Experimental Design for Three Independent Factors for Ethanol, oil yield, predicted and residual values of RSM and ANN.

Std	F_1	F_2	F_3	EKO Oil yield % (w w^{-1})	Predicted value (RSM)	Residue (RSM)	Predicted value (ANN)	Residue (ANN)
1	30	150	50	26.01	26.21	-0.1975	26.008	0.0016445
2	50	150	50	32.55	32.55	0.0025	32.552	0.0016984
3	30	200	50	33.30	33.51	-0.2050	33.299	0.0010548
4	50	200	50	29.57	29.57	0.0000	29.568	0.0018724
5	30	175	40	26.70	26.50	0.2050	26.702	0.0024643
6	50	175	40	29.57	29.57	0.0000	29.57	0.00041155
7	30	175	60	26.70	26.50	0.2025	26.705	0.0051787
8	50	175	60	29.57	29.57	0.0000	29.57	5.8986E-5
9	40	150	40	36.67	36.47	0.1975	36.663	0.0068047
10	40	200	40	36.42	36.42	0.0050	36.429	0.0085301
11	40	150	60	35.00	35.00	-0.0025	34.999	0.00051272
12	40	200	60	33.61	33.62	-0.0050	33.611	0.001284
13	40	175	50	33.11	33.10	0.0073	29.581	3.5289
14	40	175	50	30.03	30.23	-0.2023	29.581	0.4489
15	40	175	50	29.57	29.37	0.0000	29.581	0.0111
16	40	175	50	25.63	25.64	-0.0073	29.581	3.9511
17	40	175	50	29.57	29.57	0.0000	29.581	0.0111

Variance Analysis of the Solvents

The equation for the response in terms of coded factors for the Box-Behnken (explained in the methodology) surface quadratic model is used in the computation is given as:

In Table 3(a) showed the regression coefficient and significance response surface quadratic for n-hexane while Table 3(b) showed that of the ethanol solvent. The coefficient of determination (R^2) which is derived from the formula as (R^2) = (TSS – RSS) / TSS; Where: TSS – Total Sum of Squares = Σ (Yi – Ym)^2, RSS – Residual Sum of Squares =Σ (Yi – Y^)^2 and Y^ is the predicted value of the model, Yi is the value and Ym is the mean value. The coefficient of determination derived for as n-hexane is 99.97%, and R^2 (adj) is 99.92%, while for ethanol (R^2) is 99.89% and R^2 (adj) is 99.89% also; the coefficient of determination (R^2) for n-hexane is 99.99% and 99.899% for ethanol (ANNs). The two (R^2) for both n-hexane and ethanol in RSM and ANNs show a high consistency between the experimented values and the predicted values as seen in Table 4(b) and (d). The R^2 for the two solvents showed average stability between the experimented values and the predicted values. The lack of fit is the ratio MSLF to MSPE which is given as MSLF/MSPE; where MSLF Lack of fit mean square. MSPE Pure error mean square is 0.0013 for n-hexane and has known for ethanol i.e. the model is significant for the response for n-hexane only. Figures 4 (a) and (b) show the graphs of the predicted and the actual values for the solvents. It was observed that n-hexane gave the highest oil yields compared to ethanol solvent. The analysis in Tables 4(b) and 4(c), gives a clear significance due to the F-value for lack of fit which is *2384.79* for n-hexane and 703.86 for ethanol. This significance is confirmed by Tables 4 (a) and (d) which show the p-value of 0.0001 for the ANOVA of surface quadratic Model of Variance both n-hexane and ethanol respectively.

Table 3 (a): Regression coefficient and significance of response surface quadratic for-hexane.

Factor	Coefficient estimate	df	Standard error	95%CL Low	95%CL High	VIF
Intercept	15.23	1	0.2615	14.61	15.84	1
F_1	1.92	1	0.0947	1.70	2.15	1
F_2	2.19	1	0.0947	1.97	2.41	1
F_3	26.26	1	0.3528	25.42	27.09	1
F_1F_2	1.17	1	0.0312	1.09	1.24	1
F_1F_3	-1.60	1	0.0609	-1.74	-1.46	1
F_2F_3	-1.26	1	0.0609	-1.41	-1.12	1
F_1^2	-2.65	1	0.0304	-2.72	-2.58	1
F_2^2	0.1445	1	0.0304	0.0725	0.2165	1
F_3^2	-7.64	1	0.1157	-7.91	-7.36	1

Table 3 (b): Regression coefficient and significance of response surface quadratic for ethanol

Factor	Coefficient estimate	df	Standard error	95%CL Low	95%CL High	VIF
Intercept	29.57	1	0.0835	29.37	29.77	
F_1	1.55	1	0.0660	1.40	1.71	1.00
F_2	3.18	1	0.0660	3.02	3.34	1.00
F_3	-1.95	1	0.0660	-2.11	-1.80	1.00
F_1F_2	0.8825	1	0.0934	0.6616	1.10	1.00
F_1F_3	3.01	1	0.0934	2.79	3.23	1.00
F_2F_3	1.22	1	0.0934	0.9966	1.44	1.00
F_1^2	0.1888	1	0.0910	0.0315	0.3990	1.01
F_2^2	-0.2662	1	0.0910	-0.4815	-0.0510	1.01
F_3^2	3.25	1	0.0910	3.04	3.47	1.01

Table 4 (a). ANOVA for a surface quadratic model of variance table for n-hexane solvent.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	82.43	9	9.16	2348.79	< 0.0001	significant
A-SW (g)	1.61	1	1.61	412.11	< 0.0001	
B-SV (ml)	2.08	1	2.08	534.70	< 0.0001	
C-ET (min)	21.61	1	21.61	5541.20	< 0.0001	
AB	5.45	1	5.45	1398.26	< 0.0001	
AC	2.69	1	2.69	689.77	< 0.0001	
BC	1.68	1	1.68	430.09	< 0.0001	
A^2	29.52	1	29.52	7571.59	< 0.0001	
B^2	0.0879	1	0.0879	22.55	0.0021	
C^2	16.98	1	16.98	4353.90	< 0.0001	

Table 4 (b). Analysis of Variance (ANOVA) of regression for n-hexane solvent.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	82.43	9	9.16	2348.79	< 0.0001	Significant
Residual	0.0273	7	0.0039			
Lack of Fit	0.0266	3	0.0089	49.21	0.0013	Significant
Pure Error	0.0007	4	0.0002			
Cor Total	82.45	16		**Cor Total**	82.45	16
$R^2 = 0.9997$	$AdjR^2 = 0.9992$	Predicted $R^2 = 0.9948$				

Table 4 (c). ANOVA for surface quadratic model of variance table for ethanol solvent.

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	221.04	9	24.56	703.86	< 0.0001	significant
A-SW (g)	19.28	1	19.28	552.61	< 0.0001	
B-SV (ml)	80.90	1	80.90	2318.50	< 0.0001	
C-ET (min)	30.50	1	30.50	874.05	< 0.0001	
AB	3.12	1	3.12	89.28	< 0.0001	
AC	36.18	1	36.18	1036.89	< 0.0001	
BC	5.93	1	5.93	169.93	< 0.0001	
A^2	0.1422	1	0.1422	4.07	0.0833	
B^2	0.2985	1	0.2985	8.55	0.0222	
C^2	44.58	1	44.58	1277.52	< 0.0001	

Note: df is the degree of freedom

Table 4 (d). Analysis of Variance (ANOVA) of regression for ethanol solvent.

Source	Sum of Squares	df	Mean Square
Model	221.04	9	24.56
Residual	0.2443	7	0.0349
Lack of Fit	0.2443	3	0.0814
Pure Error	0.0000	4	0.0000
Cor Total	221.28	16	
$R^2 = 0.9989$	$AdjR^2 = 0.9823$	Predicted $R^2 = 0.9989$	

Evaluation of RSM and ANN in the Oil Extraction Optimization

In Table 2 (a) and (b) the average values of independent variables for 17 experimental runs at an average of 40 min extraction time, 175 ml solvents, and 50 g sample weight gives an average predicted value of RSM as 35.21 which is less than the average predicted value of ANN which is 37.21 for n-hexane solvent, likewise for ethanol solvent the average predicted value of 31.118 of ANN is higher than the average predicted value of 30.80, this means for both solvents ANN has a higher predicted value for optimization, which means it is a better model for optimization of *Elaeis guinness* kernel oil. Furthermore, the 2D contour and 3D response surface plots are graphic representations of the interactions between two or three variables. The nature of the curves shows that the relationship between the variables, where the elliptical shape is an indication of the good interaction of the two variables and a circular shape indicates no interaction. The contour and graph for both RSM and ANN are presented to evaluate the interactive effect of the three variables via both models. The 2D contour and 3D response surface plots for the two solvents are shown in Figures 3 (a) and (b) for RSM software, the chosen model equation shows the relationship between the independent and the dependent variables, as seen in Figures 4 (a) and (b) for ANN. Figures 3 (a) and 3(b) showed the highest oil yield observed at the lowest sample weight. It was also noted that the highest solvent volume was when the highest oil yield was gotten, meaning that solvents volume has so much significance in the percentage of oil extracted. The same trend is observed in Figures 4 (a) and (b) for the solvents.

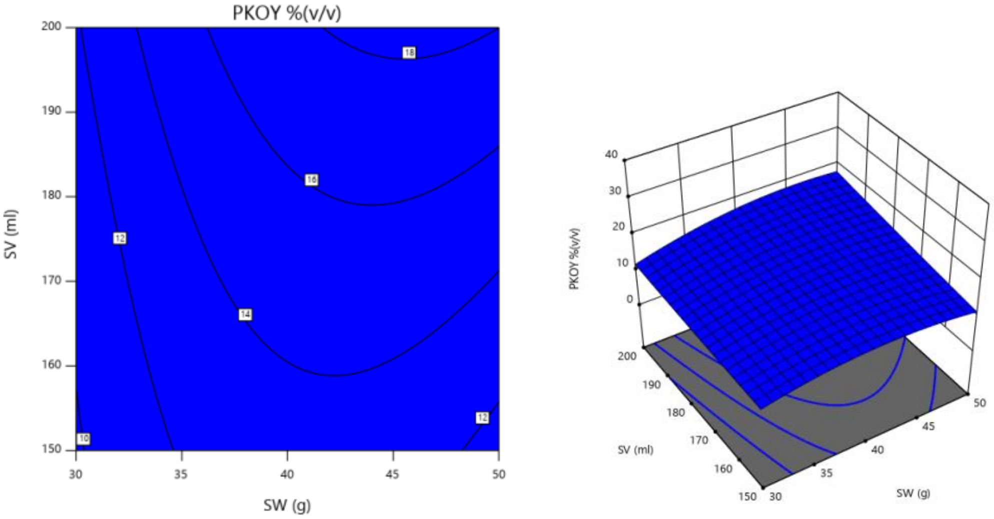

Figure 3 (a). The contour and 3D response surface plots for the effects of solvent volume, sample weight and their relationship to oil yield at zero solvent volume for n-hexane.

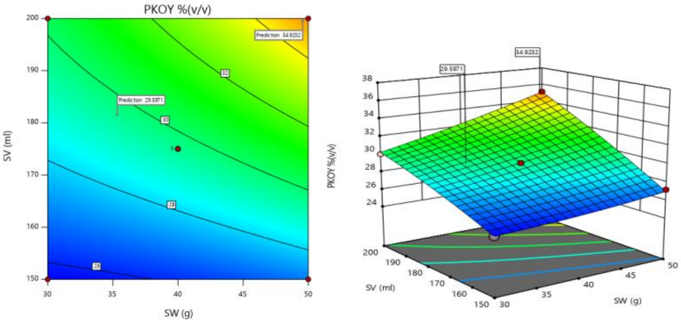

Figure 3 (b). The contour and 3D response surface plots for the effects of solvent volume, sample weight and their relationship to oil yield at zero sample weight for ethanol.

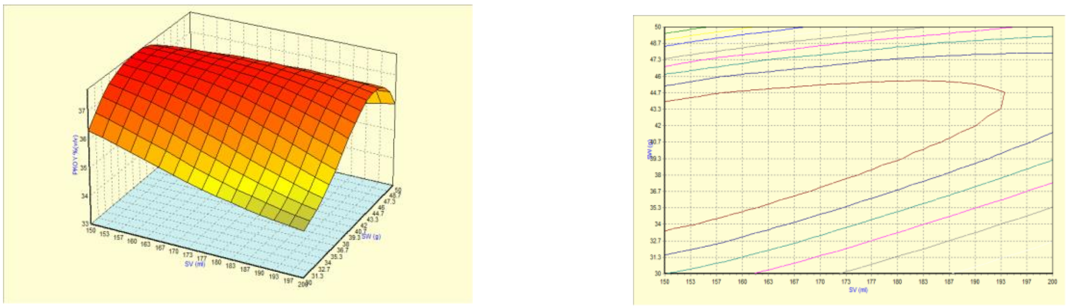

Figure 4 (a). The contour and 3D response surface plots for the effects of solvent volume, sample weight and their relationship to oil yield at zero sample weight for n-hexane (ANN).

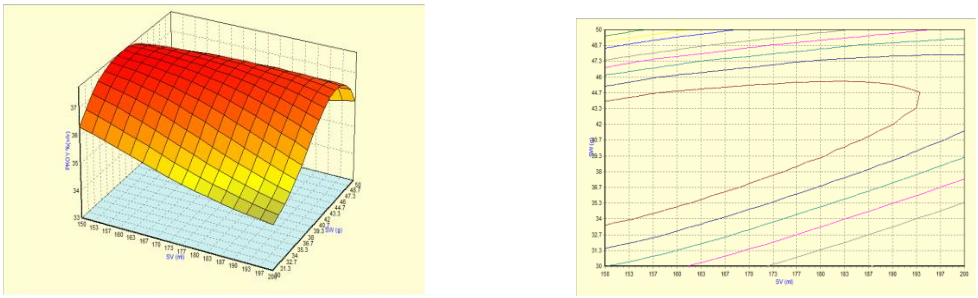

Figure 4 (b). The Contour and 3D response surface plots for the effects of solvent volume, sample weight and their relationship to oil yield at zero solvent volume for ethanol (ANN).

Figure 5(a) and (b) for RSM model and Figure 6 ANNs: The plots showed the effect of extraction time and solvent volume at a reciprocal relation with oil yield when sample weight is at zero level. RSM showed that the optimal yield of palm kernel seed would be 37.68% for n-hexane, at the following optimized conditions: sample weight 40 g, the solvent volume of 175 ml and extraction time of 50 min and 36.67 for Ethanol with the solvent volume of 175 ml and extraction time of 50 min for the optimized conditions. Average values are calculated for optimal factor values in two independent replicates as; 37.038% for n-hexane and 36.045% for ethanol, and this value was well within the range predicted by the model and ANN gave the yield of 37.693% (w w^{-1}) at the following conditions sample weight of 40 g, the solvent volume of 150 ml and extraction time of 60 min. This evaluation indicates that even at different independent variables levels and with different solvents that RSM and ANN software can be applied to the optimization.

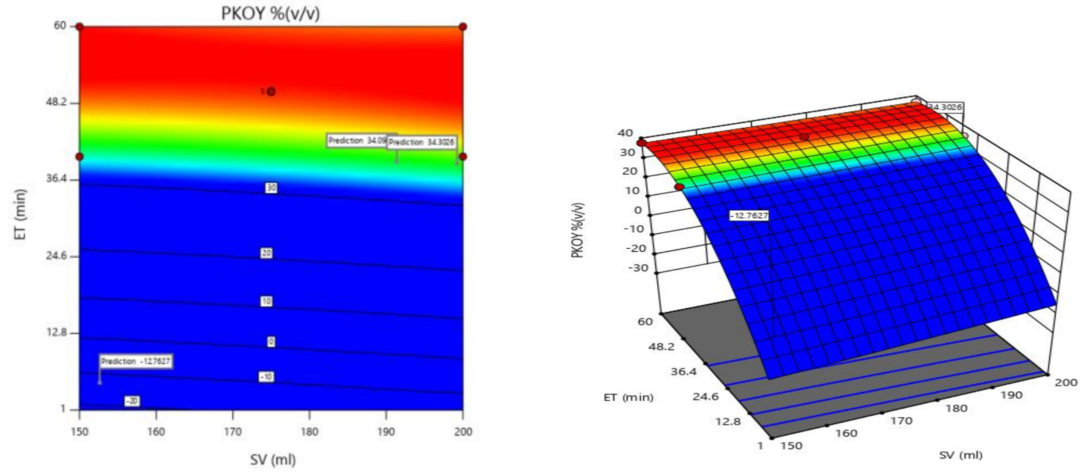

Figure 5 (a). The contour and 3D response surface plots for the effects of extraction time, solvent volume and their relationship to oil yield at zero sample weight for n-hexane.

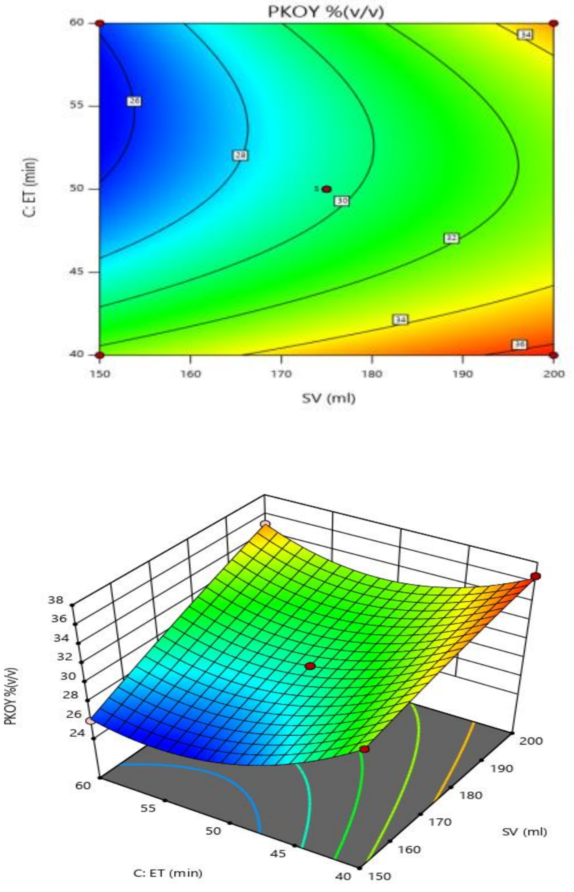

Figure 5 (b). The contour and 3D response surface plots for the effects of extraction time, solvent volume and their relationship to oil yield at zero sample weight for ethanol.

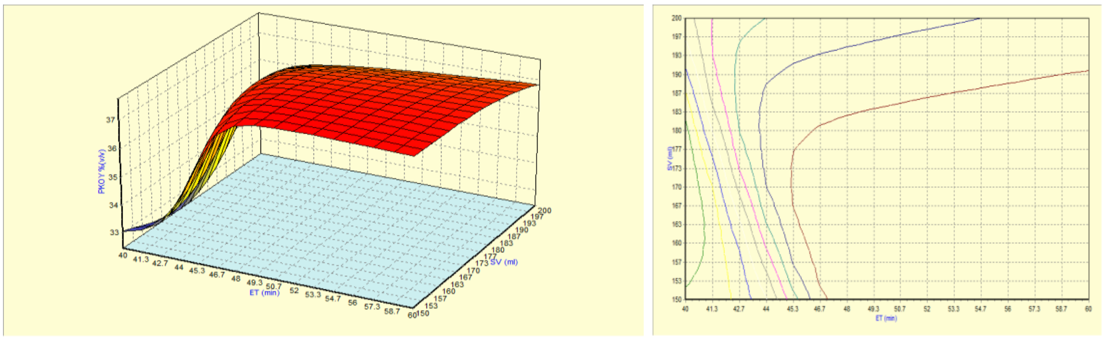

Figure 6. The contour and 3D response surface plots for the effects of solvent volume, extraction time, and their reciprocal interaction on oil yield keep sample weight constant at zero level for hexane (ANN).

CONCLUSION

It is clear that to meet the global need for the use of vegetable oil, extraction and optimization of oilseed is inevitable, therefore this research is conducted using three variable independent factors which are sample weight, solvent volume, and extraction time with a specific investigation on the performance of n-hexane and ethanol as solvents. The n-hexane solvent better term of oil extraction than ethanol, however, Capello *et al.* (2007), opined that ethanol is better terms of environmental health and renewability since ethanol is less toxic, and renewable, but n-hexane is a pollutant when emitted during extraction and react with other air pollutants with the product that is hazardous to environmental health. It was also noted that the highest solvent volume was when the highest oil yield was gotten, meaning that solvents volume has so much significance in the percentage of oil extracted. The evaluation indicated that even at different independent variables levels and with different solvents RSM and ANNs software's can be adequately used for optimization in extracting oil, then proved that both models are appropriate for representing the actual relationship of the required factors, and it buttresses the fact that ANNs is better than RSM. It recommended that further research should be concentrate on finding non-toxic solvents that can equal or better yield than n-hexane.

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DECLARATION OF COMPETING INTEREST

The author declares that she has no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The author is responsible for all parts of this article.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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