Statistical Model for Groundnut Oil Extraction for Food Sustainability

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Abstract

Groundnut oil was extracted using solvent extraction method, the process of extraction was investigated to check the effect of moisture content, extraction temperature and extraction time on the percentage oil yield obtained from groundnut seeds. The experiment carried out was designed with the aid of central composite design of response surface methodology while maintaining a constant particle size of 0.6mm throughout the experiment. The optimum percentage oil yield of 50.85% was obtained at moisture content, extraction temperature and extraction time of 6% (wet basis), 60^0C and extraction time of 8hr respectively. While, the least value of 32.37% was obtained at moisture content, extraction temperature and extraction time of 18% (wet basis), 40^0C and 4hr respectively. The data obtained were used to investigate the effect of moisture content, extraction temperature and extraction time on percentage oil yield. A quadratic model was developed to predict the percentage oil yield at a given combination of the process factors. All the factors under investigated has a significant effect on the percentage oil yield obtained from groundnut seeds. The validation results of the developed model showed that there is good agreement between the experiment and predicted values.

Keyword; Oil Yield; Model; Central Composite Design, Response Surface Methodology.

1.0 Introduction

Edible plant oil is an important contributor to diet in many countries, serving as a good source of protein, lipid and fatty acids for human nutrition (sanders 2002). It has been considered to be more desirable dietary ingredient than saturated animal fats because of its wide range of health benefits (Bucher et al., 2002). Apart from it uses in cooking foods, edible oils are also used as raw materials for the production of soap, paints, detergent and cosmetics. In Nigeria, the most popular vegetable oil plant material is groundnut oil because of the abundance and easy availability. As a result of increase in population, the available sources of vegetable oil no longer meet the increasing demands of domestic and industrial sectors (Olajide 2000). Therefore, this study work toward

investigating the effect of extraction factors (moisture contents, extraction temperature and extraction time) on the percentage oil yield obtained from groundnut seeds using solvent extraction method, developing a statistical model and validation of the developed model for extraction of oil from groundnut seeds. Optimization of the extraction process to increase the percentage oil yield obtained from groundnut seeds.

2.0 Materials and Methods

2.1 Sample Preparation

Groundnut seeds used in this study were obtained from Towobowo Market, Igboora, Oyo State of Nigeria. After the seeds were obtained, they were cracked and their shells were carefully removed to obtain the kernels. Thereafter, sorted and clean to remove damage seeds and impurities. they were dried at 50^0C until a constant moisture content of 10.20% (wet basis) was obtained, after which they were milled to a particle size of 0.6mm. The milled seeds were conditioned to desired moisture level using the procedure describe by Siyanbola, et al., (2020).

2.2 Experimental Design

The experiment carried out were designed with the aid of design expert 11 software using central composite design of response surface methodology. In designing the experiment, the factors considered were the moisture content, extraction temperature and extraction time, while the response of each experiment was chosen to be the percentage oil yield obtained from the seeds. The maximum and minimum level used for the factors is given in Table 1. A total of twenty experimental runs were obtained and carried out using soxhlet apparatus.

Table 1 fact0rs and their levels f0r central c0mp0site design

Variables	Symb0l	Levels	
		Minimum	Maximum
Moisture Content (%)	A	6	18
Extracti0n temperature (◦C)	B	40	60
Extraction Time (hr)	C	4	8

2.3 Extraction of Oil from Groundnut Seeds Using Solvent Method.

Oil was extracted using the procedure by Siyanbola, et al., (2020) for the conditioned seeds at various moisture content, extraction temperature and extraction time levels as stated in the experimental design and maintaining a constant particle size of 0.6mm. Hexane was used as the solvent of extraction.

2.4 Model Development, Validation and Optimization

The percentage oil yield obtained from the experiments were entered into the appropriate column in Design Expert. The response together with the factors considered were analyzed. A quadratic model was developed. Using the model, optimization of the percentage oil yield was carried out and the values of the factors required to give optimum oil yield were obtained. The goals of all the factors was set to be in range and the response (percentage oil yield) was maximized. Validation of optimum conditions found was achieved by carrying out an extraction experiment at a selected set of optimum values of moisture content, extraction temperature and extraction time.

3.0 Results and Discussions

3.1 Percentage Oil Yield Obtained from Groundnut Seeds

Table 2. Experimental Design and Response

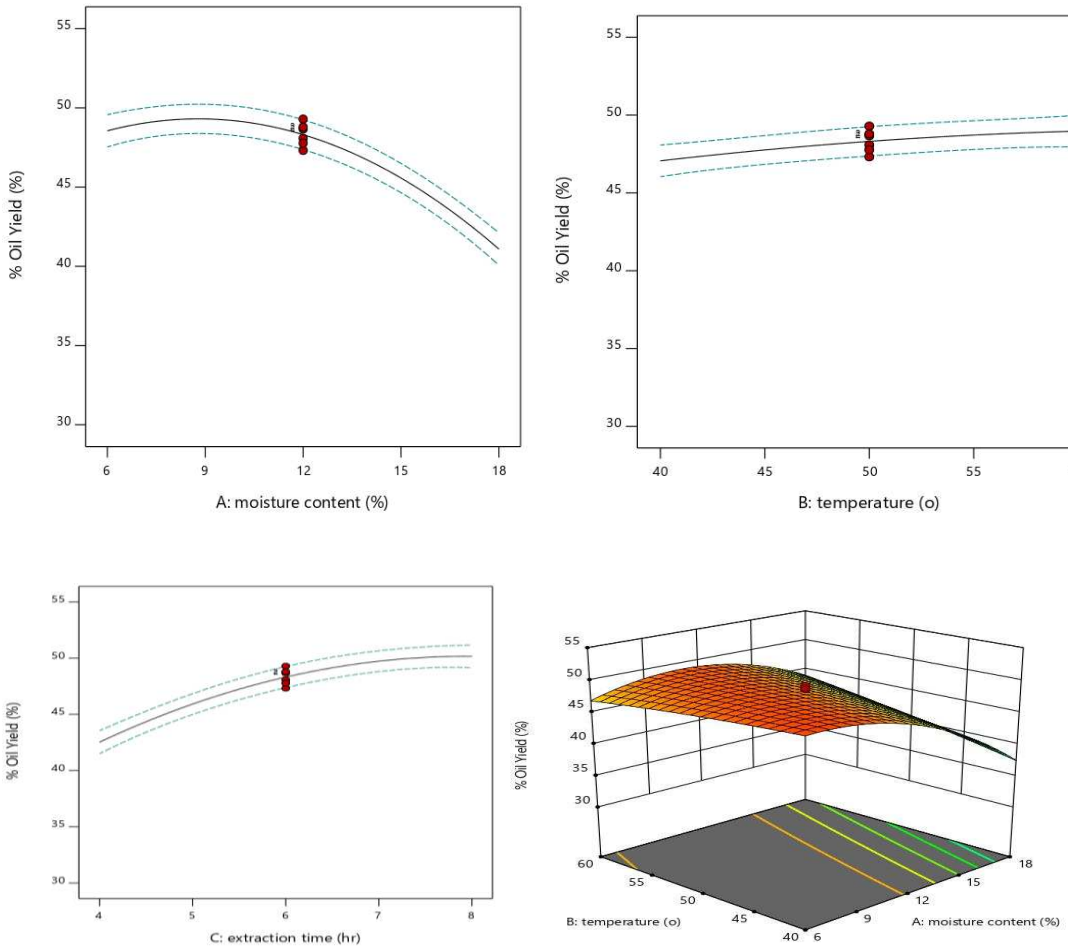
Runs	Moisture content (%)	Extraction Temperature (^{0}C)	Extraction Time (hr)	% Oil Yield
1	18	40	4	32.37
2	22.0908	50	6	32.87
3	12	50	2.63641	35.69
4	18	60	4	37.52
5	18	40	8	38.58
6	6	60	4	39.73
7	1.90924	50	6	43.69
8	12	33.1821	6	45.37
9	18	60	8	45.83
10	6	40	4	46.59
11	12	50	6	47.32
12	12	50	6	47.77
13	12	50	6	48.08
14	12	50	6	48.67
15	12	50	6	48.79
16	12	66.8179	6	49.26
17	12	50	6	49.29
18	12	50	9.36359	49.45
19	6	40	8	49.89
20	6	60	8	50.85

The results obtained after the extraction of the oil from groundnut seeds is presented in table 2. The factors, moisture contents, extraction temperature and extraction time were combined in the experiment to obtain the

percentage oil yield as the response. The variation of oil yield obtained indicated that the considered factors have effects on the extraction of oil from groundnut seeds. It was observed that the highest percentage oil yield of 50.85% was obtained at moisture content, extraction temperature and extraction time of 6%, 60^0C and 8hr respectively. While the least oil yield of 32.37% was obtained at moisture content, extraction temperature and extraction time of 18%, 40^0C, 4hr respectively. The value obtained in this study has shown to be higher than the range of 16.56% to 32.33% reported by Olajide, et al., (2014) in the optimization of oil yield from groundnut kernel (arachis hypogeae) in hydraulic press using response surface methodology. The higher result obtained in this study indicated that solvent extraction method is more effective than traditional and mechanical methods of extracting oil from oil bearing seed

3.2 Effects of Moisture Contents, Extraction Temperature and Extraction Time on percentage oil Yield

Figure 1Effect of factors considered on percentage oil yield of groundnut seeds



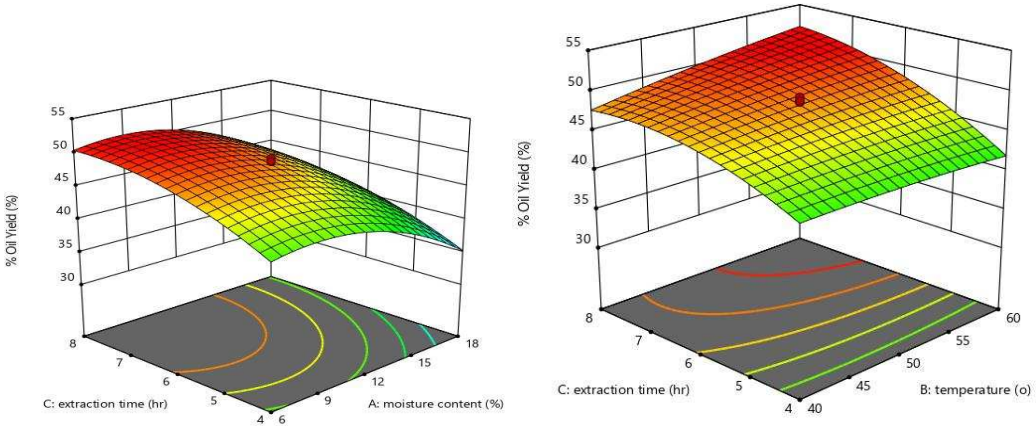


figure 1 shows that, increase in moisture content has an effect on the percentage oil yield obtained from groundnut seeds. The highest percentage oil yield of 50.85% was obtained at moisture content of 6% while the lowest oil yield of 32.37% was obtained at a moisture content of 18%. Different researcher have established the fact that, moisture content has an effect on the quantity of oil obtained from oil bearing seeds. Investigations by Abidakun et al. (2012) revealed that highest quantity of oil was obtained at 6% moisture content for dika nut. Similarly, Siyanbola et al., (2020) found out that the variation of moisture content has effect on the oil yield of Azardirachta indica seeds with the highest percentage oil yield of 43.73% obtained at a moisture content of 6%. Olajide (2000) reported an optimum moisture content of 6.6% (wet basis) and 13% (wet basis) showed a substantial improvement in oil recovery in both groundnut and sheanut kernels respectively. Akinoso et al. (2006) observed that increased in oil yield of sesame seeds was as a result of decreased in moisture content. Maximum oil yield of 50.4% at an optimum moisture content of 4.6% wet basis was obtained. This implies that, the more the moisture content, the lower the percentage oil yield.

As shown in figure 1, The higher the temperature, the higher the extraction rate. Different research and investigation have established the fact that, extraction temperature has effects on the quantity of oil obtained from oil bearing seeds. Siyanbola et al., (2020) reported that, extraction time has effect on the oil yield of Azardirachta indica seeds. The highest percentage oil yield of 43.73% was obtained at an extraction time of 6hr. Oniya et al. (2017) reported that, there is a reduction in oil yield for the extraction of oil from sand box seed as the extraction temperature decrease. It was observed that increase in extraction time favors the percentage oil yield of groundnut seeds as shown in figure 1, as much time is required for extraction.

3.3 Model Development and Validation

Table 3 Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	669.84	9	74.43	69.63	0.0001
A-moisture content	190.13	1	190.13	177.87	0.0001
B-temperature	12.46	1	12.46	11.65	0.0066
C-extraction time	198.62	1	198.62	185.81	0.0001
AB	41.86	1	41.86	39.16	0.0001
AC	0.0013	1	0.0013	0.0012	0.9734
BC	12.30	1	12.30	11.51	0.0069
A^2	175.42	1	175.42	164.11	0.0001
B^2	1.25	1	1.25	1.17	0.3048
C^2	56.05	1	56.05	52.44	0.0001
Residual	10.69	10	1.07		
Lack of Fit	8.04	5	1.61	3.04	0.1237
Pure Error	2.64	5	0.5289		
Cor Total	680.53	19			

Table 4. Model summary

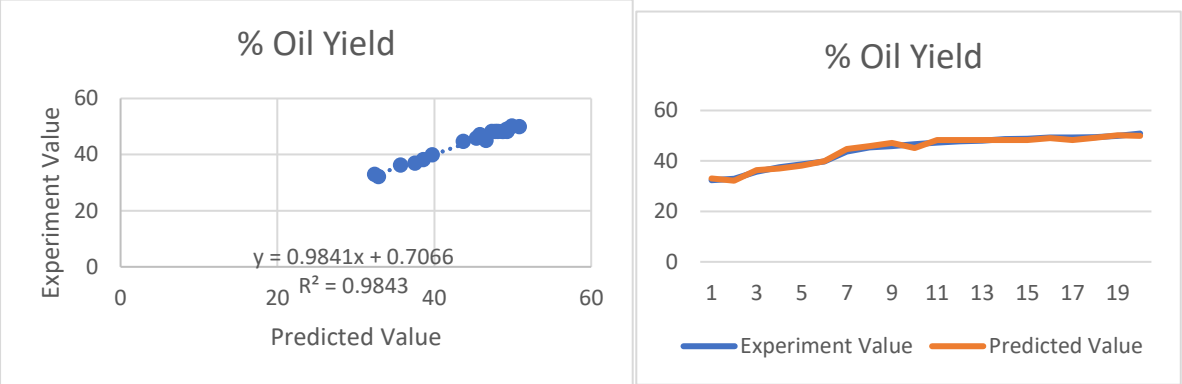
S	R-sq	R-sq(adj)	R-sq(pred)
1.03389	98.43%	97.02%	89.52%

Model Equation

$$\%\ Oil\ Yield = 48.31 - 3.73A + 0.9550B + 3.81C + 2.29AB + 0.0125AC + 1.24BC - 3.49A^2 - 0.2946B^2 - 1.97C^2 \quad \text{(i)}$$

As shown in Table 3, the p-value was used to measure how significant the effect of the factors on the percentage oil yield obtained from groundnut seeds. From the results obtained, it was discovered the entire model was significant because its p-value was less than 0.05 based on 95% confidence level. Also, each of the terms of the model was found to be significant as result of the obtained p-value less than 0.05. The results obtained revealed that variation of moisture content, extraction temperature and extraction time has a significant effect on groundnut oil yield using solvent extraction method. The R-squared value obtained was found to be 98.43%. The obtained R-squared value indicated that the developed model equation for the percentage oil yield was a good representative of the system. In order to see the performances of the developed model, it was used to predict the oil yield and the results obtained were compared with the experimental values of the percentage oil yield as shown in Figure 1. It was discovered that, there was a good agreement between the results obtained from the predicted and those recorded from the experiments carried out. The graphical comparison of the results was found to be supporting the R-squared value obtained from the analysis of variance of the developed quadratic model.

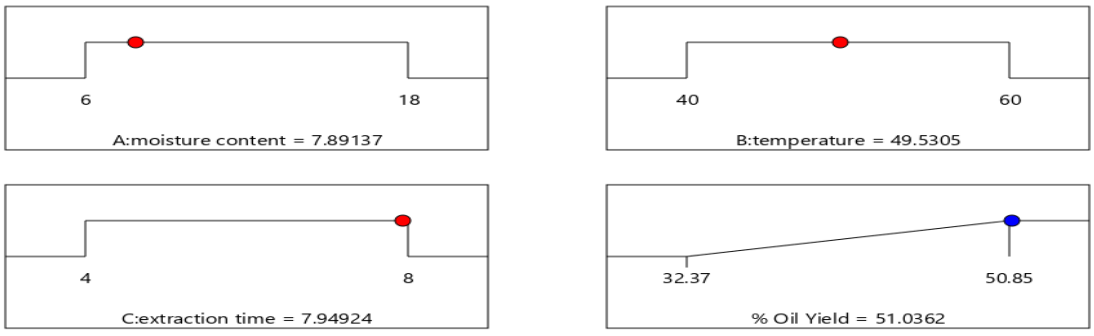
Figure 2. Experiment and Predicted Value of Groundnut Oil Yield



3.4 Response Optimization

Design-Expert 11 software was used to optimize the percentage oil yield of groundnut seeds. The factors considered (moisture content, extraction temperature and extraction time) were set in range with the response set to maximum level. It was revealed that the combination of 7.8914% moisture content, 49.5305^{0}C extraction temperature and extraction time of 7.9492hr as predicted gave an optimum percentage oil yield of 51.0362% as shown in Figure 3. The predicted variables obtained were subjected to experimental validation. Oil was extracted using the combined factors predicted and a percentage oil yield of 51.21% was obtained. This shows a close value with the predicted value.

Figure 3. Optimization Plot of Percentage Oil Yield



4.0 Conclusion

Groundnut seeds with an initial moisture content of 10.20% (wet basis) was obtained and preconditioned to the various moisture content of 6%, 12%, and 18%, extraction temperature of 40^0, 50^{0}C and 60^{0}C and extraction time of 4hr, 6hr and 8hr as stated in the central composite design of response surface methodology using Design-expert 11. Groundnut oil was extracted using solvent extraction method, the process of extraction was investigated to

check the effect of the factors considered, maintaining a constant particle size of 0.6mm. The optimum percentage oil yield of 50.85% was obtained at moisture content, extraction temperature and extraction time of 6% (wet basis), 60^0C and extraction time of 8hr respectively. While, the least value of 32.37% was obtained at moisture content, extraction temperature and extraction time of 18% (wet basis), 40^0C and 4hr respectively.

Using the data obtained from solvent oil extraction from groundnut seeds with Soxhlet apparatus, effect of moisture content, extraction temperature and extraction time on percentage oil yield was determined and a quadratic model equation was developed to predict oil yield at a given combination of the process factors. All the factors under investigated has a significant effect on the percentage oil yield obtained from groundnut seeds. The validation results of the developed model showed that there is good agreement between the experiment and predicted values.

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