Optimization of Extraction Process and Characterization of *Adansonia Digitata* (Baobab) Seed Oil

*** E. Omale[1], C. E. Gimba[2], A.A. Nuhu[2], S.E. Abechi[2], O.R.A. Iyun[2]**
[1]. Department of Chemistry,
Federal University of Health Sciences Otukpo, Benue State, Nigeria
[2.] Department of Chemistry,
Ahmadu Bello University, Zaria, Nigeria
*Corresponding author; lizogbeh@yahoo.co.uk
https://doi.org/10.56201/ijccp.vol.12.no7.2026.pg65.71

Abstract:
This study employed a two-level full factorial design of experiments to optimize the solvent extraction of baobab seed oil. Eight experimental runs were conducted using three independent variables: solvent volume, extraction time, and sample weight. A first-order regression model adequately described the experimental data, with an R^2 value of 0.9999, an F-value of 2758.64, and a P-value of 0.0146, indicating a statistically significant model. The predicted values agreed closely with the experimental results. The optimum oil yield of 22.52% was obtained by extracting 30.00 g of pulverized baobab seed with 200.00 cm^3 of n-hexane for 90 minutes. The extracted oil exhibited a high degree of unsaturation, with an iodine value of 98.35 ± 0.99 $gI_2/100g$ and a saponification value of 210.27 ± 0.12 mgKOH/g. The acid value, peroxide value, and free fatty acid (FFA) content were 13.48 ± 0.04 mgKOH/g, 25.50 ± 0.13 meqKOH/g, and 6.78 ± 0.05%, respectively. These physicochemical properties were generally consistent with values reported in previous studies. The findings demonstrate the effectiveness of the two-level full factorial design in optimizing baobab seed oil extraction and provide insights into the physicochemical properties of the extracted oil.

Key Words: *Optimization, Baobab, Extraction, Oil, Solvent.*

Introduction

Baobab seed contain extractable oil, which have been reported to be of some commercial value. Oil from baobab has been utilized by various communities as food, medicine, for cosmetic and as fuel. Baobab seed oil is highly stable and is an excellent source of essential and other fatty acids including linoleic acid and linolenic acid. With regards to its diverse applications, Baobab seeds are being exploited on daily basis to meet up with the increasing demands on its oil, hence a high-performance technique of separating the oil content from its seed for optimal seed oil yield is essential. Seed oil yield may depend generally on the quality of the seed variety, soil and environmental conditions around the source plant, as well as on the pretreatment procedure adopted and the particular extraction method(s) used. The major aim of comparatively selecting any of those oil extraction methods is to obtain a quality oil yield in terms of sufficient quantity, clarity and purity after extraction, and/or qualitative oil residue for higher economic value of the extraction process. Solvent extraction method, which is considered as one of the most efficient methods in vegetable oil extraction, with less residual oil left in the cake or meal [1] is most

widely used for separation of the oil content from its seeds. Solvent extraction method is very effective with high yield and consistent performance [2,3]. In addition, certain factors like solvent volume, extraction time and pulverized sample weight can be manipulated during extraction in order to maximize oil yield [4]. Optimization tools like Response Surface Methodology have also been employed to obtain high oil yield from various plant seeds [5,6]. In this study, statistical analysis of oil yield was performed using Design Expert 6.0.6. Full Factorial Design of Experiment was applied to optimize the solvent extraction process and the quality of the oil extracted was evaluated by carrying out physicochemical properties and fatty acid analysis of the seed oil.

Materials and Methods

Sample Collection

Baobab (*Adansonia digitata*) seeds were purchased from Sabon-Gari market Zaria, Kaduna State, Nigeria. The hard epicarp seeds were sundried and cracked manually. The fleshy part was removed and dried at room temperature. The cleaned seeds were then pulverized and kept for further analysis.

Experimental Design and Analysis of Extracted oil

The experimental design, as well as the methods adopted for the extraction and analysis of the baobab seed oil is as reported in our previous work [4].

Results and Discussion

Table 1: Experimental design matrix and response for baobab seed oil extraction.

Std	SW (g)	ET (min.)	SV (cm^3)	EY (%)	PV (%)
1	30.00	60.00	150.00	12.53	12.56
2	50.00	60.00	150.00	11.8	11.77
3	30.00	90.00	150.00	17.49	17.46
4	50.00	90.00	150.00	17.03	17.06
5	30.00	60.00	200.00	21.76	21.73
6	50.00	60.00	200.00	14.18	14.21
7	**30.00**	**90.00**	**200.00**	**22.52**	**22.55**
8	50.00	90.00	200.00	15.44	15.41

SW- Sample weight, ET- Extraction time, SV- Solvent volume, EY- Experimental oil yield and PY- Predicted Oil Yield

Table 2: ANOVA for Factorial Model of baobab oil extraction

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	109.45	6	18.24	2758.64	0.0146	significant
A	31.40	1	31.40	4749.01	0.0092	
B	18.64	1	18.64	2818.22	0.0120	
C	28.31	1	28.31	4281.71	0.0097	
AB	0.074	1	0.074	11.21	0.1848	
AC	22.68	1	22.68	3429.88	0.0109	

BC	8.34	1	8.34	1261.79	0.0179
Residual	6.612E-003	1	6.612E-003		
Cor Total	109.46	7			

Std. Dev.	0.081	R-Squared	0.9999
Mean	6.59	Adj R-Squared	0.9996
C.V.	0.49	Pred R-Squared	0.9961
PRESS	0.42	Adeq Precision	141.687

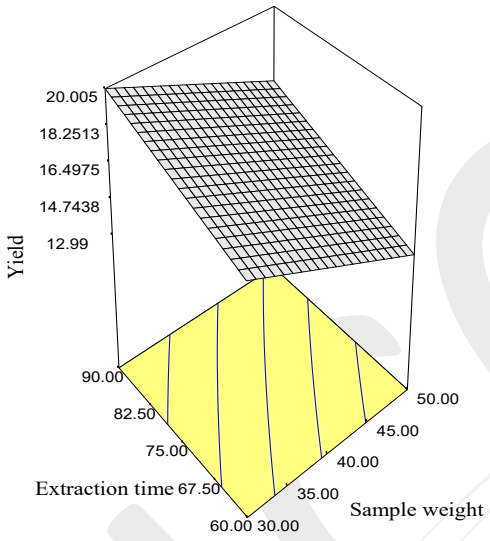


Figure 1: Response surface for two dependent factors of extraction time and sample weight.

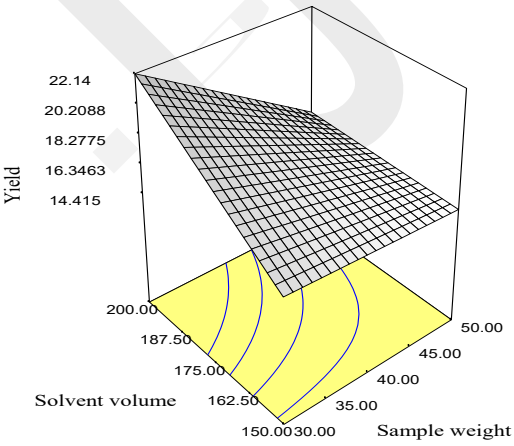


Figure 2: Response surface for two dependent factors of solvent volume and sample weight.

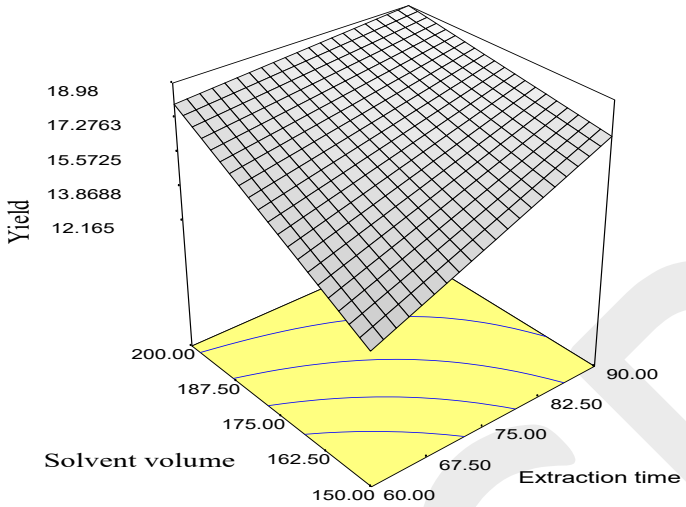


Figure 3: Response surface for two dependent factors of solvent volume and extraction time

Table 3: Fatty acid composition (FAC) of the baobab seed oil.

FAC	From	Composition (%)
Palmitic	C16:0	27.09
Linoelaidic	C18:2	17.44
Elaidic	C18:1	17.02
Stearic	C18:0	11.11
Cis-oleic	C18:1	18.65
Myristic	C14:0	2.17
11-14-Eicosadienoic	C20:2	1.73
Arachidic	C20:0	2.19
Behenic	C22:0	2.61
Total SFA		45.16
Total UFA		54.84

SFA- Saturated fatty acids
UFA- Unsaturated fatty acids

Baobab seeds are highly rich in oil, Although difference in species and environmental factors as well as processes involved in the extraction of the oil, have been reported to affect the nature as well as the oil yield from its seeds, hence the need for optimum operating condition to avoid wastages of raw materials, energy, time e.t.c. which can be achieved by investigating multiple factors in all possible conditions. Design expert 6.0.6 software was employed to analyze the result from Table 1. The analysis of variance (ANOVA) of the regression equation for oil extracted (Table 2) was done using F values at confidence level of 95% (α=0.05) to determine

the effects of the main and interactive factors. From Table 2, the three linear terms (A, B & C), and two cross products (AC& BC) were significant (i.e. Prob<0.05) model terms for the oil extraction process. The Model high F-value (2758.64) with low P- value (0.0146) implied a high significance for the regression model of the oil extraction. The predicted determination coefficient value of 0.9961 is in reasonable agreement with the adjusted determination coefficient value which was 0.9996 for the analyses. "Adequate Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable; in this case the ratio of 141.687 indicated an adequate signal. Therefore, the model can be used to navigate the design space. Diagnostics case statistics study, carried out for the oil shows a close relationship between the actual value and the predicted value for all model terms. The model was validated; values obtained had no outlier, an indication that the precision and accuracy of the analyses were good. The Normal probability of Studentized residual plots, studentized residuals versus predicted values, and Box-Cox plot for power transforms were also good.

Eq. 1 below, defines the relationship between the oil yield (Y) and the coded values of sample weight (A), extraction time (B) and solvent volume (C) for baobab oil extraction [7]. It shows that sample weight and solvent volume positively contributed to the quantity of oil extracted from the seeds; the interaction between extraction time and solvent volume also improved the oil yield.

$$Y = 2.24 + 0.21A - 0.17B + 0.28C - 0.047A * B - 0.084A * C + 0.13B * C \ldots\ldots\ldots\ldots \text{(Eq. 1)}$$

The 3-D dimensional surface plot representing the effect of extraction time and sample weight and their reciprocal interaction on baobab oil yield while keeping solvent volume constant at zero level (Figure 1) shows that the oil yield is favoured at lower sample weight for longer period of extraction. The interaction between solvent volume and sample weight (Figure 2) shows that baobab oil yield is favored when solvent volume increases with decreased sample weight and vice-versa. Figure 3 shows the interaction between solvent volume and extraction time. Baobab oil yield is enhanced at high solvent volume and longer extraction time.

Physicochemical Analysis of Baobab oil

Baobab seeds, gave a clear light-yellow oil yield of 22.55%. This value obtained is in line with the range value of 22% - 35% reported by other researchers [8]. The refractive index of oils is a measure of how much a light ray is bent when it passes from air into the oil and it usually depends on the density of the oil. The refractive index and relative density of baobab oil was found to be 1.487 and 0.919 respectively, which is also in agreement with the value of 1.498 and 0.928 reported by other researchers [9]. The refractive index and relative density values of oils are, generally, physical measures for checking the adulteration of oils since different oils have characteristic density and refractive index. The moisture content of oils is the loss in mass of the oils on heating at 105±1^{o}C under operating conditions. The moisture content of the Baobab oil was 0.029%. The peroxide value, which is a predominant test for oxidative rancidity in oil, is used to measure the extent to which rancidity has occurred during storage of oils; thus high peroxide value of oil indicates a poor resistance of the oil to peroxidation during storage [10]. The seed oil gave a peroxide value of 25.50meqKOH/g, which is comparable with the range of 0.93-56.00meqKOH/g for some for seed oils [11]. The value obtained for our oil indicates that the oil is stable and may not be susceptible to oxidative rancidity if produced from fresh seeds and stored properly. The iodine value measures the degree of unsaturation in oil. Studies have shown that as the degree of unsaturation increases, the iodine value increases and the liability of the oil to become rancid by oxidation also increases. The iodine value of the seed oil is

93.35gI_2/100g. Oils with iodine values less than 130 are regarded as non – drying oils and are suitable for paint making [11].

The saponification value of the oil was found to be 210.27mgKOH/g. A saponification value this large indicates a high proportion of fatty acids of low molecular weight. This shows that the oil may have potentials for use in soap making and cosmetics industries and for the thermal stabilization of polyvinyl chloride (PVC) and could also be a source of essential fatty acids required in the body [12]. In addition, this saponification value is within the range for edible oils as reported by other researchers [13].

The acid value of oil corresponds to the amount of carboxylic acid groups in its constituent fatty acids and is given in mgKOH/g sample. The older an oil is, the higher the acid value as triglycerides are converted into fatty acids and glycerol upon aging. The acid value of baobab seed oil was found to be 13.48mgKOH/g and %FFA value of 6.78. These values were slightly above the value reported by other researchers [9]. Analysis of the fatty acid composition of the oil shows that the oil is unsaturated (table 3). Behenic acid present in the oil is also an indication that the oil may find use in the cosmetic industries, as this acid is often used to give hair conditioners and moisturizers their smoothing properties, it is also use in lubricating oils and as solvent evaporation retarder in paint removers.

Conclusion

Baobab seeds contain oil, which was characterized based on its physicochemical properties and was found to conform to that reported for oils which find use in cooking, soap making, paint and also in biodiesel production. The process of extraction was optimized to improve the oil yield. The various factors investigated had various degrees of effect on this yield. It was found that the best oil yield was obtainable when extraction time was at high level and both sample weight and solvent volume where at low levels. The oil also contains essential fatty acids, with palmitic acid and linoelaidic acid being the most abundant.

References

[1] Tayde, S., Patnaik, M., Bhagt, S.L. and Renge, V.C. (2011). Epoxidation of vegetable oils: A review. *International Journal of Advanced Engineering Technology,* II (IV): 491-501.

[2] Bhuiya, M.M.K., Rasul, M.G., Khan, M.M.K; Ashwath, N; Azad, A.K. and Mofijur, M. (2015). Optimization of oil extraction process from Australian Native Beauty Leaf Seed. (Calophyllum innophyllum). 7th International Conference on Applied Energy ICAE2015. *Energy Procedia*, 75:56-61.

[3] Ikya, J.K., Umenger, L.N. and Iorbee, A. (2013). Effects of extraction methods on the yield and quality characteristics of oils from shea nut. *Journal of Food Resource Science*, 2:1-12.

[4] Ogbeh, E., Gimba C.E., Nuhu, A.A., Abechi, S.E., Iyun, O.R.A. (2018). Extraction and Characterization of Cola Millenii K. Schum (Monkey Cola) Seed Oil: Optimization Using Full Factorial Design of Experiment. *Nigerian Journal of Pharmaceutical and Applied Science Research*, 7(2): 1-6

[5] Fatima A., R.,and Rahman, A. (2020): Effect of Roasting Temperature and Duration on the Quality of Oil from Walnut (Plukenetia conophorum) using response surface methodology, *Asian Food Science Journal*, 13(4):1-12

[6] Umar Hassan (2021) Extraction and Optimisation of Oil from Baobab (*Adansonia digitata*) Seed Kernel Using Grey Relational Analysis. *Journal of Chemical Engineering and Bioanalytical Chemistry.* 2(2); 118-123

[7] Adepoju TF, Olawale O, Abiodun AO, (2013). Optimization, kinetic degradation and quality characterization of oil extracted from Nigeria Hibiscus sabdariffa oil seeds. *International Journal of Engineering Research and Technology*. 2(11): 3856-3875.

[8] Salisu, A., Veronica, E., David, B., and Michael, A., (2015). Nutraceutical evaluation of baobab (Adansonia digitata L.) seeds and physicochemical properties of its oil, *Annals of Biological Sciences*, 3 (2):13-19.

[9] Oyeleke, G.O., Salam, M.A., and Adetoro, R.O.,(2012). Some aspect of nutrient analysis of seed, pulp and oil of baobab (Adansonia digitata L.). *Journal of Environmental Science, Toxicology and Food Technology*, 1(4), 32-35.

[10] Mohammed MI, Hamza ZU, (2008). Physicochemical properties of oil extracted from sesamum indicum I.seeds grown in Jigawa State- Nigeria. *Journal of Applied Science and Environment.* 12 (2):99-101.

[11] Aremu M O, Ibrahim H, and Bamidele T O, (2015). Physicochemical Characteristics of the Oils Extracted from Some Nigerian Plant Foods – A Review, *Chemical and Process Engineering Research.* 32, 3652.

[12] Akanni MS, Adekunle AS, Oluyemi EA, (2001). Physicochemical properties of some nonconventional oil seeds. *Journal of food technology*. 3(2): 177-181.

[13] Eromosele CC, Eromosele CO, Akintoye AO, Komolafe TO, (1994).Characterization of oils extracted from wild-gathered tropical plant seeds Nigeria. *Journal of American oil Content.* 75 (8): 1031-1035.