International Journal of Scientific Research and Modern Technology (IJSRMT) ijsrmt.com
Volume 4, Issue 3, 2025
DOI: https://doi.org/10.38124/ijsrmt.v4i3.369

Temperature Effects on Granular Morphology and Oil Properties of *Chrysophyllum albidum* (African Star Apple) Cotyledon: A Response Surface Approach

R. Akinoso[1]; O. T. Gbokan[2]; S.O. Ogundipe[3]

[1,2] Department of Food Technology, University of Ibadan, Nigeria
[3] Department of Food Science and Technology, College of Agricultural and Environmental Sciences, University of Georgia, 100, Cedar Street, Athens, GA, 30602, USA

Publication Date: 2025/04/18

ABSTRACT

This research was designed to study temperature effects on granular morphology of Chrysophyllum *albidum* (African star apple) cotyledon and constituents of its oil using response surface methodology. The independent variables were roasting temperature (120ºC - 200ºC) and roasting duration (10 - 40 min). Granular morphology, oil yield, free fatty acids, specific gravity and chemical compositions were responses. The particle surface of the samples showed an inter-twined tiny tissue that is compact and smooth. Temperature variations were reflected in the cell morphology, indicating that roasting at increasing temperatures significantly affects the cellular structure of *Chrysophyllum albidum* cotyledons. The percentage oil yield ranged between 11.76 and 14.16 %. Maximum oil yield recorded was 14.16% and achieved at 192.43ºC and 30min duration. Percentage content of free fatty acid in *Chrysophyllum albidum* cotyledon oil ranged from 1.26 to 2.25%. Heat treatment significantly influence free fatty acids contents. The highest specific gravity was achieved at temperature and duration of 192.43ºC and 30min respectively, while the lowest specific gravity value was achieved at temperature and duration of 107ºC and 30min. Eighteen (18) compounds were identified. The dominating compound was 9, 12-Octadecadienoic acid (Z, Z) with percentage weight of 28.08 ± 2.8 while the least was Tetracontane having percentage weight of 0.69 ± 0.068. Total percentages of unsaturated fatty acids in the compound were 73.56%. These findings suggest that *Chrysophyllum albidum* cotyledons have the potential to serve as a viable source of edible oil.

Keywords: *Chrysophyllum Albidum Seed, Edible Oil, Roasting Condition, Oil Extraction, Oil Properties.*

I. INTRODUCTION

Animals and plants are sources of edible oils. Due to health concern, preference for consumption is tilted towards plants-based oils (Mazzocchi *et al.,* 2021). Some plants that serve as sources of edible oil includes soybean, groundnut, melon, canola, palm kernel, oil palm, coconut, sesame seed, olive, sunflower, safflower, rape seed and cotton seed (Wen *et al.,* 2023).These plants oils serve in human diet as sources of oil soluble vitamins, higher calories in comparison with protein and carbohydrates, some essential fatty acids and flavourant. In addition to utilization for human consumption, oils from plants are also useful in industries for production of soaps, detergents, oleo-chemicals, drug, textiles and paints. Continuous rise in population, health workers sensitization and consciousness of consumers have increased the preference for edible plant oils. To mitigate the challenges caused by this trend, attention must be shifted to extraction of edible oils from underutilized oilseeds (Raji and Akinoso, 2020). *Chrysophyllum albidum* seed is one of such unexploited sources of phyto-oil which could be a good alternative to the familiar oil seeds.

Chrysophyllum albidum (African star apple) is a forest fruit tree that belongsto *Sapotaceae* family. It is a popular seasonal fruit (Ewanshiha*et al.*,2017) normally consumed with its pericarp in the West Africa region. Several studies have shown that the fruit has varying health benefits. It has been discovered to be a natural remedy for constipation, mouth gum, toothache, dental and sore throat ailments as it is used in herbal medicines (Adeboyejo, Oguntoye and Awe, 2019). In some traditions, it is used to treat yellow fever and malaria. *Chrysophyllum albidum*seed have been rarely exploited for oil meant for consumption (Abiodun and Oladapo, 2011). Hence, investigating properties, and enhancement on yield of recovered oil from *Chrysophyllum albidum* cotyledon will add more value to the seed utilization. This research was designed to study effects of temperature changes on granular morphology of Chrysophyllum *albidum* cotyledon and constituents of its oil using response surface methodology.

II. MATERIALS AND METHODS

- *Experimental Design using Response Surface Methodology*

Seeds of *Chrysophyllum albidum* (African star apple) used for the study were cracked to separate to shell and cotyledon. The cotyledon (**Plate 1**) was grinded using hammer mill (WF-130, Shanghai Universal Pharmaceutical Machinery Company Limited, China). A central composite rotatable design of response surface methodology was used to interact treatments (roasting temperature and duration). This was achieved using Design-Expert version 16.0 (stat ease Inc, Minneapolis USA) which generated 13 treatment (**Table 1**). The independent variables were roasting temperature (120^{o}C - 200^{o}C) and roasting duration (10 - 40 min.). Granular morphology, oil yield, free fatty acids, specific gravity and chemical compounds were responses. Data were subjected to ANOVA at 95% confidence level ($p<0.05$).

Plate 1a: Cotyledon

Plate 1b. Fine Sample

- *Determination of Granule Morphology of Roasted-milled Chrysophyllum albidum cotyledon*

Finely milled (200g) *Chrysophyllum albidum* cotyledon (**Plate 1b**) were spread on a stainless-steel plate and roasted using oven (model OV-160 Gallenkamp) at different temperature and time combination as indicated in **Table 1**. Scanning electron microscope (PRO: XPhenom-World, MVE01570775, Thermo Fisher Scientific, USA) was used to determine morphology of *Chrysophyllum albidum* cotyledon granules. They were magnified at x 300 and x 1500 for better visibility.

- *Determination of Oil Yield*

Oil was extracted from the heated, milled samples using the Soxhlet extraction method described by Rajesh et al. (2023), with n-hexane as the extraction solvent. The oil yield, expressed as a percentage, is calculated using **Equation 1**, which is the ratio of the difference between the sample initial and final weights to the total weight, multiplied by 100.

$$Oil\ yield\ (\%) = \frac{weight\ \ of\ extracted\ oil}{weight\ of\ sample}\ x\ 100\%$$

$$(Equation\ 1)$$

- *Determination of Free Fatty Acid*

Free Fatty Acid (FFA) in the extracted oil was determined using the AOCS method Ca5a – 40 (AOCS, 2020). Briefly, 1g of *Chrysophyllum albidum* cotyledon oil were mixed with 25 mL diethyl ether, 1 mL of phenolphthalein, and 25 mL of ethanol. The resulting solution was titrated against 0.5N aqueous NaOH, vigorously shook, until a permanent faint pink colour appeared and persisted for 15 sec. The percentage of FFA in the sample was calculated as stated in **Equation 2**.

$$FFA(\%) = \frac{T\ \times\ 0.0282\ \times\ 100}{W} \qquad (Equation\ 2)$$

Where T is the titre value

0.0282 is a constant

W is weight (g)

- *Determination of Specific Gravity*

Specific gravity was determined as oil density divided by density of water. Density is sample mass divided by sample volume. Briefly, an empty pycnometer bottle was weighed, filled with water and reweighed. The oil was poured into the cleaned, dried bottle and the weight recorded. The specific gravity was calculated using **Equation 3**

$$\text{Specific gravity} = \frac{W1-W2}{W3-W1} \qquad (Equation\ 3)$$

Where W_1 =weight of the empty bottle

W_2=weight of the bottle and sample

W_3=weight of the bottle and water

➢ *Optimization of the Oil Yield*

The optimum process condition for high oil yield and low free fatty acid was achieved using Design-Expert version 16.0 (stat ease Inc, Minneapolis, USA). The desired properties were maximum oil yield; minimum free fatty acid and specific gravity in range.

➢ *Determination of Chemical Composition of the Oil*

Chromatographic analysis of the oil samples was conducted using a Varian 3800/4000 gas chromatograph-mass spectrometer (SpectraLab Scientific Inc, Markham, ON, Canada) equipped with an Agilent split/splitless injector. Analytes were separated using Thomas Scientific BP5 capillary column (30 m × 0.25 mm × 0.25 µm film thickness, Swedesboro, NJ, USA). The GC oven temperature program was set as follows: the initial temperature of 50°C was maintained for 2 min, followed by a ramp at 10°C/min to 240°C, where it was held for 6 min. The temperature was then further increased at 10°C/min to 340°C and held for an additional 6 min, resulting in a total run time of 43 min. The injector and interface temperatures were set at 250˚C and 300˚C, respectively. The GC was operated in split mode at a ratio of 50:1 with nitrogen as the carrier gas in constant flow mode (1.2 mL/min), and 1µL of sample was injected. The mass analyzer was operated in electron impact (EI) mode with an ionization energy of 70 eV. The scanned mass range was 30–1000 *m/z*, and the detector voltage was set at 1150 V. Compound identification was achieved by comparing retention times with those of known standard compounds and by using the NIST-MS (National Institute of Standards and Technology MS) library spectral database. The compounds were quantified as relative percentage areas, derived from the integrator. No response factors were calculated.

III. RESULTS AND DISCUSSION

➢ *Granular Morphology of Roasted-milled Chrysophyllum albidum cotyledon*

The particle surface of the samples showed an inter-twined tiny tissue that is compact and smooth (**Plates A – G**). Changes in temperatures reflected in the cell morphology which shows roasting at increasing temperature has a significant effect on *Chrysophyllum albidum* cotyledon cell. Complete cell destruction in the sample that had the highest roasting temperature and duration (180ºC for 45 min.) implied that prolong heating at high temperature could significantly rupture the cell of African star apple seed. Also, intercellular apertures formation and cavities noticed in these samples micrographs which according to Xiaoping *et al.*, (2024) maybe a result of the disintegration and destruction of cell walls. Mapengo, Ray and Emmambux (2022) also in their work further reiterated that temperature magnitude and time duration are two important factors influencing the morphology of materials.

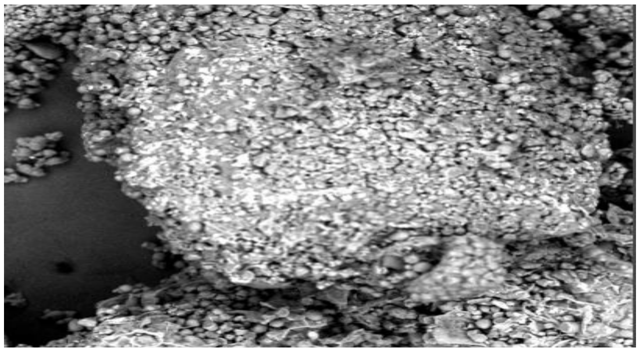


Plate 2 A1. X 1500. Roasted at 107.57ºC for 30 min

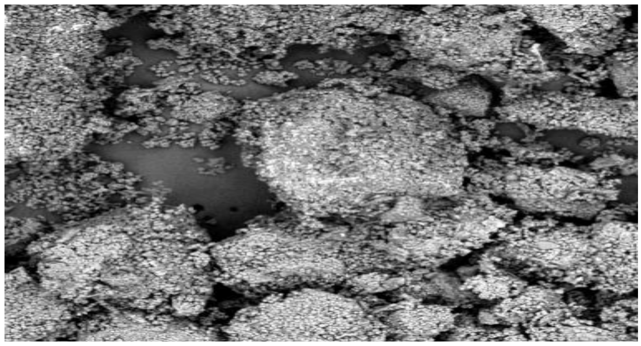


Plate 2 A2. X 300. Roasted at 107.57ºC for 30 min

Plate 2 B1. X 1500. Roasted at 120ºC for 15min

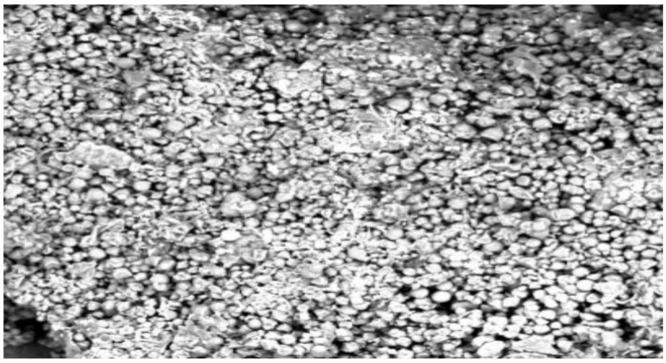


Plate 2 B2. X 300. Roasted at 120ºC for 15min

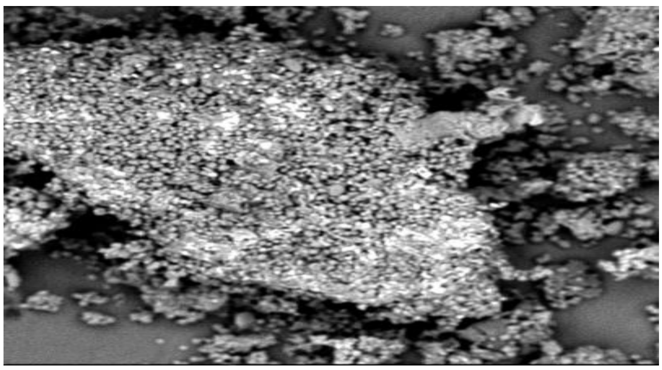


Plate 2 C1. X 1500. Roasted at 150ºC for 8.79min

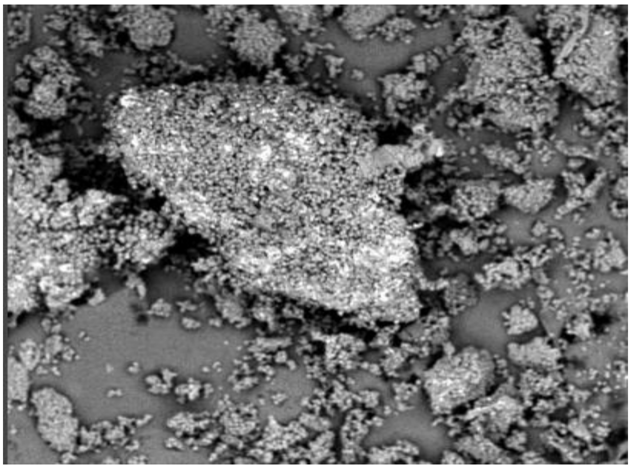


Plate 2 C2. X 300. Roasted at 150ºC for 8.79min

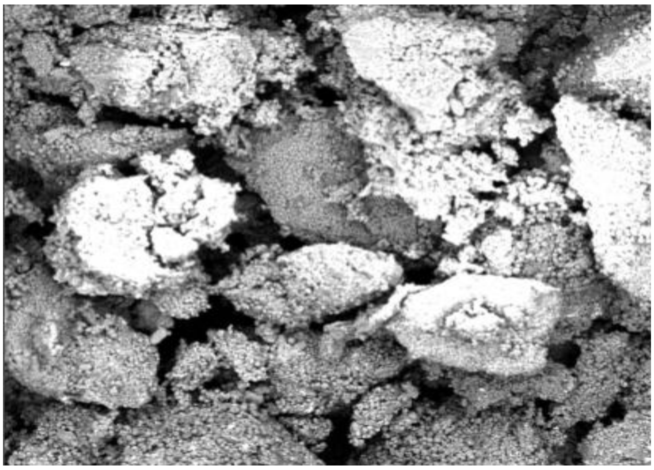


Plate 2 E2. X 300. Roasted at 150ºC for 51.21min

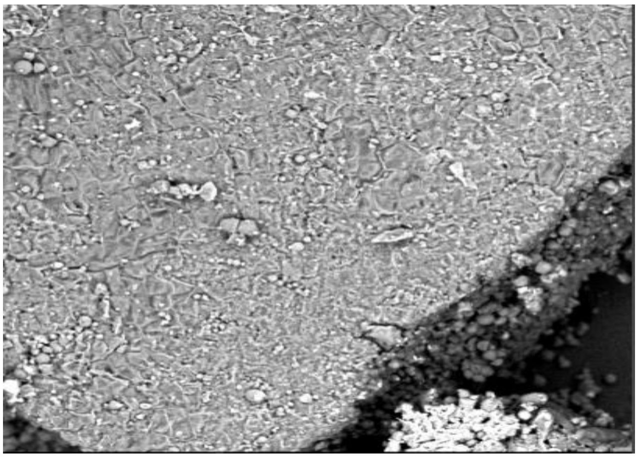


Plate 2 D1. X 1500. Roasted at 150ºC for30min

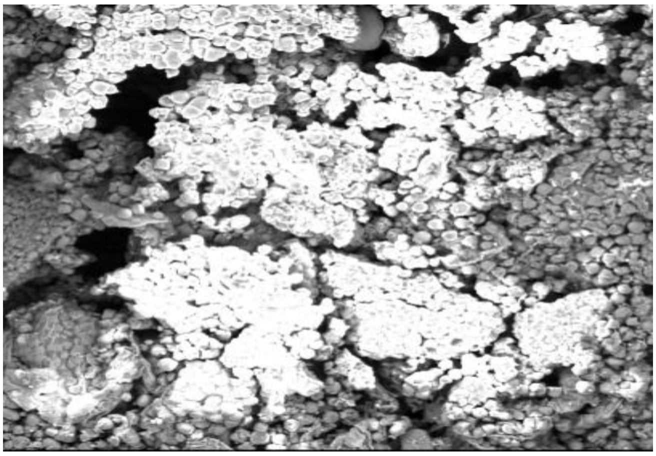


Plate 2 F1. X 1500. Roasted at 120ºC for 45min

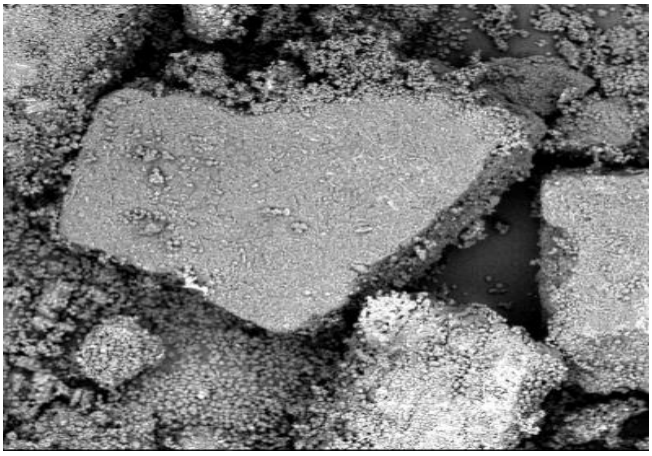


Plate 2 D2. X 300. Roasted at 150ºC for 30min

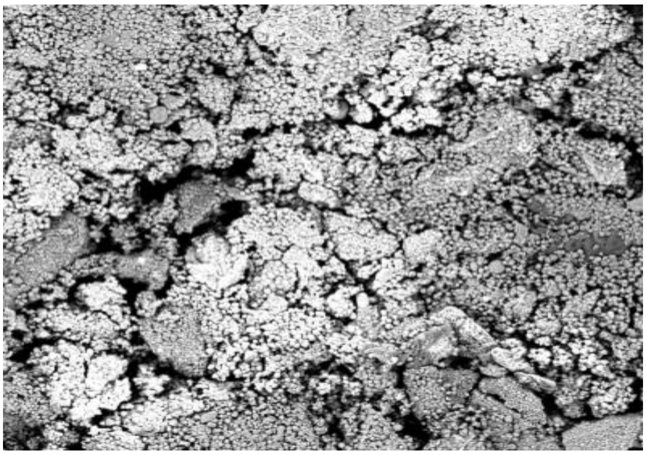


Plate 2 F2. X 300. Roasted at 120ºC for 45min

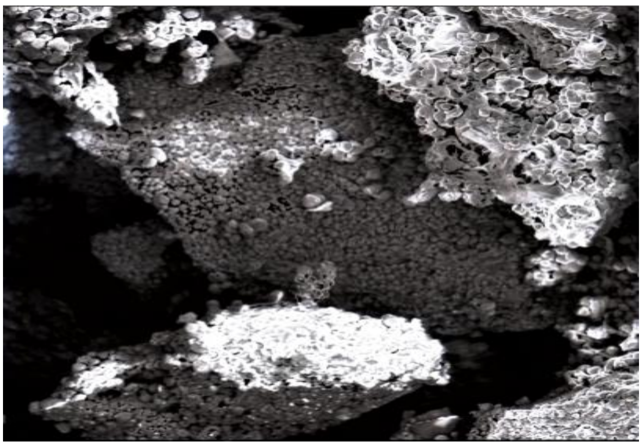


Plate 2 E1. X 1500. Roasted at 150ºC for 51.21min


Plate 2 G2. X 300. Roasted at 180ºC for 45min

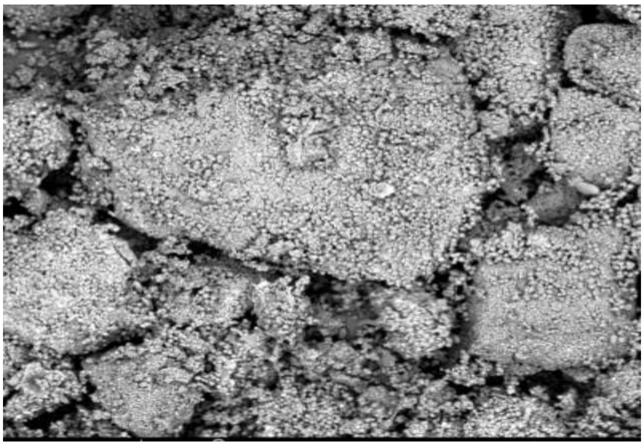


Plate 2 G1. X 1500. Roasted at 180°C for45min

- *Oil Yield*

The percentage oil yield from *Chrysophyllum albidum* cotyledon ranged between 11.76 and 14.16 %. Maximum oil yield recorded was 14.16% and achieved at 192.43°C and 30min duration (**Table 1**). The minimum oil yield was 11.76% at 150°C roasting temperature and 8.78min roasting duration. The oil yield recorded in this study was found to be slightly higher than the average oil yield of 10.71% reported by (Adebayo *et al.*, 2012). As shown in **Table 1**, there was variation of oil yield according to each treatment parameter. *Chrysophyllum albidum* cotyledon oil increased at different roasting temperatures with an increasing roasting duration. Several factors including thermal treatment, particle size, extraction methods, equipment efficiency and varietal differences of oil seeds have been associated with quantity and quality of oil recovered from oil seeds (Raji and Akinoso, 2020). **Equation 3**models' relationship between oil yield and heat treatment. The model revealed positive impacts of roasting temperature and duration on oil yield. However, roasting duration had higher coefficient. Heating oilseeds break down oil cells, coagulate the protein; reduce oil viscosity and moisture contents (Akinoso and Adeyanju, 2012). These characteristics aid oil recovery and flow. It should be noted that excessive heating could lead to compound hydrolysis and polymerization of some fatty acid, and escape of volatiles compounds.

$$Oil\ yield = 13.25 + 0.57A + 0.25B - 0.14A^2 - 0.50B^2 + 0.7A * B \quad (3)$$

$$p - 0.002 \qquad R^2 \quad 0.889$$

Where:

A is temperature (°C)

B is duration (min.)

Table 1 Effects of *Chrysophyllum albidum* Cotyledon Treatment on Oil Yield and Some Quality Parameters

Runs	Temperature ℃	Duration(min)	Yield (%)	Free fatty acid (%)	Specific gravity
1	150.00	30.00	13.25	1.77	0.909
2	120.00	45.00	12.34	2.11	0.8545
3	150.00	8.79	11.76	1.26	0.8363
4	192.43	30.00	14.16	1.96	0.9454
5	150.00	30.00	13.25	1.77	0.909
6	120.00	15.00	12.20	2.20	0.836
7	107.57	30.00	11.83	2.25	0.800
8	180.00	45.00	13.12	1.41	0.900
9	150.00	30.00	13.25	1.77	0.909
10	180.00	15.00	12.70	1.35	0.900
11	150.00	51.21	12.79	1.51	0.890
12	150.00	30.00	13.25	1.77	0.909
13	150.00	30.00	13.25	1.77	0.909

- *Free Fatty Acid Contents (FFA)*

Percentage content of free fatty acid in *Chrysophyllum albidum* cotyledon oil ranged from 1.26 to 2.25% (**Table 1**). The highest FFA gotten from the sample was 2.25% at 107.57^{0}C roasting temperature and 30min roasting duration. It was observed that FFA decreased as temperature increased. At temperature of 150^{0}C and duration of 8.79 min, minimum free fatty acid value of 1.26% was recorded. It is an indication that potency of enzyme lipase that initiated the hydrolytic reactions in oil has been reduced. Values obtained for *Chrysophyllum albidum* cotyledon oil in this study suggested its stability under storage, low FFA content of in an edible oil is desirable for good quality. Also, at high temperature and duration, there was noticeable decrease in FFA value. This means that at constant temperatures of roasting and a proportionate increase in roasting duration, the free fatty content reduces. These changes agree with Akinoso (2006) where he stated that changes in FFA content are dependent on the duration and temperature of the heating oil seeds to other factors. The lower values of FFA as affected by roasting duration could be as a result of reduction of moisture, inactivation of enzymes and the activities of anthocyanins (antioxidant) has been proved to act against both hydrolytic and photolytic reactions (Gharehbeglou, Sarabandi and Akbarbaglu, 2024). Without doubt, this pretreatment will help to maintain maximum 2% FFA content in unrefined edible oil (Codex, 2023)

According to **Equation 4**, impacts of roasting temperature, roasting duration, and the interaction of the two variables (roasting temperature and duration) were negative which shows that free fatty acid decreased with a reduction in each value.

$$FFA\ (\%) = 1.77 - 0.37A - 0.083B - 1.875\ x\ 10^{-3}A^2 - 0.012\ B^2 + 0.038A * B \quad (4)$$

$$p - 0.016 \qquad R^2 \quad 0.958$$

- *Specific Gravity (SG)*

Oil specific gravity is an indicator in determining the quality of oil (Iloamaeke *et al.*, 2024). This oil specific gravity ranged between 0.800 and 0.945. Least specific gravity of 0.800 was lower to those reported in literature for other oil seed like palm oil 0.926 and palm kernel oil 0.910(Iloamaeke *et al.*, 2024). The extracted oil specific gravity range (0.80-0.945) however is in concur with the work done by (Akinoso and Oni, 2012) on melon seed oil (0.815-0.95), and Bamgboye and Adejumo, (2010) investigation on roselle seed oil where they reported 0.955 value for specific gravity. The highest specific gravity was achieved at roasting temperature and roasting duration of 192.43°C and 30min, while the lowest specific gravity value was achieved at roasting temperature and roasting duration of 107°C and 30min. (**Table 1**).It was observed heat treatment significantly affected the oil specific gravity.

$$SG = 0.91 + 0.39A + 0.012B - 0.017A^2 - 0.022B^2 - 4.625\ x\ 10^{-3}\ A * B \quad (5)$$

$$p - 0.043 \qquad R^2 \quad 0.918$$

- *Optimum Yield with Low Free Fatty Acid*

Three solutions were found for high oil yield with low free fatty acid. These solutions have desirability range of 0.842 to 0.850 (**Table 2**). The treatment combination that gave highest oil yield (13.72 %); least free fatty acid (1.37 %) and highest desirability value of 0.850 was chosen.

Table 2 Optimised Conditions Solutions

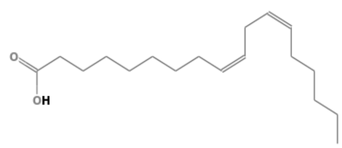
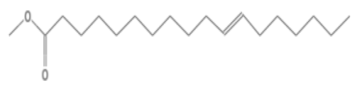
Run	**Temperature ℃**	**Duration (min)**	**Yield (%)**	**Free fatty acid (%)**	**Specific gravity**	**Desirability**
1	180.00	36.73	13.72	1.37	0.9303	0.850
2	180.00	38.61	13.70	1.37	0.9284	0.849
3	180.00	32.33	13.72	1.39	0.9320	0.842

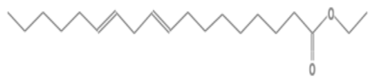
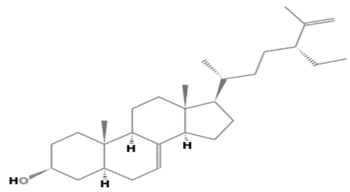
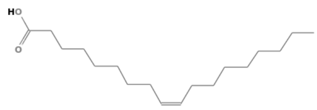
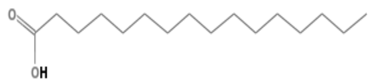
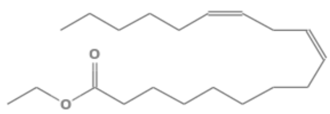
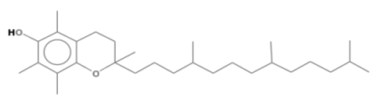
- *Chemical Composition of Chrysophyllum albidum Cotyledon Oil*

Eighteen (18) compounds were identified (**Table 3**). The dominating compound was 9, 12-Octadecadienoic acid (Z, Z) {$C_{18}H_{32}O_2$} with percentage weight of 28.08 ± 2.8 while the least was Tetracontane {$C_{40}H_{82}$} having percentage weight of 0.69 ± 0.068. Large percentage (**Table 4**) of the compounds have food industry applications including utilization for cooking, food additives, flavouring and emulsification (Voon *et al.*, 2024). They also possess anti-inflammatory, antimicrobial and antioxidant properties. 9,12-Octadecadienoic acid (Z,Z) (28.08 ± 2.8%), 11-Octadecenoic acid methyl ester (12.11±0.38),9,12-Octadecadienoic acid ethyl ester (10.21±0.63), Squalene (7.75±0.7), Oleic acid (4.46±0.40), 9-Octadecyne (3.95±0.27), Linoleic acid ethyl ester(3.81±0.28), Undecylenic acid (2.33±0.13), and 7-pentadecene (0.86±0.037) are unsaturated fatty acids. Total percentages of unsaturated fatty acids in the compound were 73.56%. Unsaturated fatty acids are known to improve heart health (Voon *et al.*, 2024). These compounds are generally recognized as safe by Food and Drug Agency (FDA, 2024)

Heat treatment of the cotyledon was found to significantly influence percentage distribution of the compounds (**Table 5a, 5b and 5c**). This is traceable to the presence of high quantity of unsaturated fatty acids in compounds. Unsaturated fatty acids have double bond which make them unstable and reactive. Also, unsaturated fatty acids have low melting and boiling points (Khaled *et. al.*, 2024). It should be noted that 1-Nonadecene and Methyl stearate contents were not influenced by application of heat. This may be associated with having straight-chain molecule (**Table 3**), and linear structure is known to contribute to thermal stability of compounds (Khaled *et. al.*, 2024). 1-Nonadecene and Methyl stearate have relatively high boiling points of 315°C and 220°C, respectively (O'Brien 2017). Roasting temperature had higher coefficients, thus more effects on the compound extraction. Coefficient of determination R^2 of the predictive model ranged 0.9620 to 0.4303. The closer of R^2 to 1, the better is the model fitness in predicting existing relationship.

Table 3 Copound Detected in Roasted *Chrysophyllum albidum* (African Star Apple) Cotyledon.

	Compound Detected	**Mol.Formula**	**Structures**
Y1	9,12-Octadecadienoic acid (Z, Z)	$C_{18}H_{32}O_2$	
Y2	11-Octadecenoic acid, methyl ester	$C_{19}H_{36}O_2$	

Y3	9,12-Octadecadienoic acid ethyl ester	$C_{20}H_{36}O_2$	
Y4	Squalene	$C_{30}H_{50}$	
Y5	1-Nonadecene	$C_{19}H_{38}$	
Y6	Methyl stearate	$C_{19}H_{38}O_2$	
Y7	Stigmasta-7,25-dien-3-ol, (3β,5α)-	$C_{29}H_{48}O$	
Y8	Oleic acid	$C_{18}H_{34}O_2$	
Y9	n-Hexadecenoic acid	$C_{16}H_{32}O_2$	
Y10	9-Octadecyne	$C_{18}H_{34}$	
Y11	Linoleic acid ethyl ester	$C_{20}H_{36}O_2$	
Y12	Vitamin E	$C_{29}H_{50}O_2$	

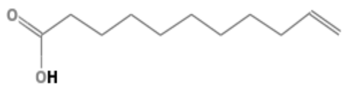
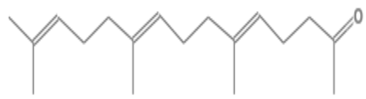
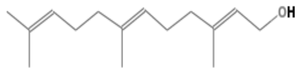
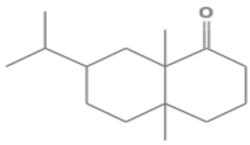
Y13	Undecylenic acid	$C_{11}H_{20}O_2$	
Y14	5,9,13-Pentadecatrien-2-one, 6,10,14-trimethyl-, (E, E)-	$C_{18}H_{30}O$	
Y15	trans-Farnesol	$C_{28}H_{48}O$	
Y16	1(2H)-Naphthalenone, octahydro-4a,8a-dimethyl-7-(1-methylethyl)-, [4aR-(4aα,7β,8aα)]-	$C_{15}H_{26}O$	
Y17	7-pentadecene	$C_{15}H_{30}$	
Y18	Tetracontane	$C_{40}H_{82}$	

Table 4a Efffects of Roasting Duration and Temperature on *Chrysophyllum albidum* Cotyledon Compounds Distribution

Roasting temperature (^oC)	**Roasting duration(min)**	**Compounds weight (%)**								
		Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**
107.57	30	20.90	10.84	10.08	9.44	6.77	5.75	4.9	4.36	4.31
120	45	20.90	10.84	10.08	9.44	6.77	5.75	4.9	4.36	4.31
150	8.79	20.38	13.91	8.8	7.93	6.50	5.46	5.21	4.99	4.55
150	30	22.95	10.98	10.26	7.21	7.20	5.25	5.23	5.04	5.00
120	15	20.07	13.12	10.74	9.33	5.92	5.36	5.04	4.96	4.62
180	15	30.11	15.24	9.35	7.33	7.15	4.00	3.39	3.06	2.92
150	51.21	20.97	10.26	10.20	7.24	7.20	7.17	5.22	5.17	5.08
180	45	34.84	13.10	12.86	6.70	4.63	3.62	3.00	2.88	2.63
150	30	22.95	10.98	10.26	7.21	7.20	5.25	5.23	5.04	5.00
150	30	22.95	10.98	10.26	7.21	7.20	5.25	5.23	5.04	5.00
150	30	22.95	10.98	10.26	7.21	7.20	5.25	5.23	5.04	5.00
150	30	22.95	10.98	10.26	7.21	7.20	5.25	5.23	5.04	5.00
192.43	30	30.11	15.24	9.35	7.33	7.15	4.00	3.39	3.06	2.92
	Std. Dev.	2.80	0.38	0.63	0.27	0.65	0.91	0.38	0.40	0.41
	Mean	24.08	12.11	10.21	7.75	6.78	5.18	4.71	4.46	4.33

Table 4b Efffects of Roasting Duration and Temperature on *Chrysophyllum albidum* Cotyledon Compounds Distribution

Roasting temperature (^oC)	**Roasting duration (min)**	**Compounds weight (%)**								
		Y10	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**	**Y18**
107.57	30	4.30	4.21	3.75	3.13	1.27	1.19	0.95	0.88	0.52
120	45	4.30	4.21	3.75	3.13	1.27	1.19	0.95	0.88	0.52
150	8.79	4.18	4.03	3.8	2.39	1.77	1.26	1.24	0.84	0.83
150	30	4.38	4.26	3.55	2.11	2.09	1.26	1.09	0.84	0.74
120	15	4.21	3.97	3.76	2.30	1.07	1.00	0.80	0.72	0.54
180	15	2.85	2.62	2.57	2.30	2.14	1.62	1.05	0.93	0.72
150	51.21	4.23	4.15	3.41	2.13	2.08	1.29	1.08	0.96	0.80

180	45	2.58	2.36	2.30	2.02	2.01	1.51	1.00	0.85	0.59
150	30	4.38	4.26	3.55	2.11	2.09	1.26	1.09	0.84	0.74
150	30	4.38	4.26	3.55	2.11	2.09	1.26	1.09	0.84	0.74
150	30	4.38	4.26	3.55	2.11	2.09	1.26	1.09	0.84	0.74
150	30	4.38	4.26	3.55	2.11	2.09	1.26	1.09	0.84	0.74
192.43	30	2.85	2.62	2.57	2.30	2.14	1.62	1.05	0.93	0.72
	Std. Dev.	0.26	0.28	0.20	0.13	0.14	0.045	0.085	0.037	0.068
	Mean	3.95	3.81	3.36	2.33	1.86	1.31	1.04	0.86	0.69

Table 5a Model Coefficients for Predicting Heat Treatments Impacts on the Compounds

Parameters	**Model coefficients**					
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**
Intercept	-0.6464	38.7704	19.2062	27.5551	-1.2459	+5.1815
A	0.1542*	-0.3441	-0.0680	-0.23356*	0.0546	-
B	0.0533	-0.2731*	-0.30725*	-0.01516	+0.2751	-
A^2	-	1.29E-03*	-	+7.12E-004*	-	-
B^2	-	3.03E-03*	-	+1.07E-003*	-	-
AB	-	0.0001	+2.317E-003*	-4.11E-004	-1.87E-003*	-
p-value	0.0027	< 0.0001	0.0145	0.0001	0.1498	-
R^2	0.6925	0.9731	0.6729	0.9558	0.4303	-

Where A is roasting temperature, and B is roasting duration

Table 5b Model Coefficients for Predicting Heat Treatments Impacts on the Compounds

	Model Coefficients					
Parameters	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**
Intercept	-9.6345	-11.2643	-13.6396	-6.6330	-7.8757	-1.0476
A	+0.2110*	+0.2412*	+0.2578*	0.1525*	0.1650	+0.0753*
B	+0.0584	-6.01E-003	+0.0639	0.0794	0.0964	0.0266
A^2	-7.68E-004*	-8.99E-004*	-9.34E-004*	-8.39E-004*	-5.97E-004*	-0.0003
B^2	-6.98E-004	-5.56E-004	-1.07E-003	-0.0008	-0.0009	-0.0002
AB	-1.38E-004	+2.33E-004	+1.11E-005	-0.0002	-0.0003	-0.0001
p-value	0.0038	0.0041	0.0041	0.0011	0.0012	0.0016
R^2	0.8815	0.8794	0.8791	0.9173	0.9155	0.9089

Table 5c Model Coefficients for Predicting Heat Treatments Impacts on the Compounds

	Model Coefficients					
Parameters	**Y13**	**Y14**	**Y15**	**Y16**	**Y17**	**Y18**
Intercept	8.2158	-7.2994	1.2817	-1.5815	0.0417	-2.0758
A	-0.0877	+0.0983*	-0.0118*	0.0310	0.0050	+0.0344*
B	0.0773	0.0666	0.0247	0.0150	0.0417	0.0059
A^2	0.0003	-0.0003	0.0001	-0.0001	-	-1.01E-004*
B^2	0.0003	-5.80E-004*	-	-	-	-
AB	-6.16E-004*	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001
p-value	0.0005	0.0008	< 0.0001	0.1654	0.0094	0.0391
R^2	0.9334	0.9269	0.9620	0.6119	0.7039	0.7589

IV. CONCLUSIONS

Response surface methodology is an efficient tool for modelling effects of heat treatment on extraction of oil from *Chrysophyllum albidum* cotyledon (African star apple). The study showed that temperature and duration of roasting the cotyledon have significant influence on yield, free fatty acids, specific gravity and compounds of the extracted *Chrysophyllum albidum* cotyledon oil. The optimum process heating conditions for *Chrysophyllum albidum* cotyledon were 180°C of roasting for 36.73min duration to get oil yield of 13.72%, free fatty acids of 1.37%, and 0.93 specific gravity. The oil contained about 73.56 % unsaturated fatty acids, vitamin E (3.36) and Stigmasta-7, 25-dien-3-ol, (3β,5α)- (4.71%), a phytosterol. These compounds are known to be edible and possess health benefits. Thus, *Chrysophyllum albidum* cotyledon has potential of being a source of edible oil.

- *Declaration of competing interest*

The authors make declaration of no financial or moral commitment to an individual or organization that which can prevent publication of this article.

REFERENCES

[1]. Abiodun, A. O., and Oladapo, A.S. (2011). Physico-chemical properties of African star apple (*Chrysophylum albidum*) components, *Nutrition & Food Science*,*41*,8-11. https://doi.org/10.1108/00346651111102847

[2]. Adebayo, S.E., Orhevba, B.A., Adeoye, P.A., Musa, J.J. and Fase, O.J. (2012) Solvent extraction and characterization of oil from African star apple (*Chrysophyllum albidum*) seeds. *Academic Research International*, *3*, 178-183.

[3]. Adeboyejo, F.O., Oguntoye, M.A., and Awe, O. E. (2019). Phytochemical components of beverages from African star apple (*Chrysophyllum albidum*) tissue fractions under ambient storage. *African Journal of Food Science*,*13*, 225-234.

[4]. Akinoso, R. (2006). Effect of moisture content, roasting duration and temperature on yield and quality of palm kernel (*Elaeis guineensis*) and sesame (*Sesamum indicum*) oils. Ph. D Thesis. Department of Agriculture and Environmental Engineering. University of Ibadan, Nigeria; 2006.

[5]. Akinoso, R. and AdeyanjuJ. A. (2012). Optimization of edible oil extraction from ofada rice bran using response surface methodology. *Food and Bioprocess Technology*, *5*, 1372–1378. https://doi.org/10.1007/s11947-010-0456-8

[6]. Akinoso, R., and Oni P. O. (2012). Optimization of solvent extracted melon seed oil using RSM. *European Journal of Lipid Science and Technology*, *114*, 607–611. https://doi.org/10.1002/ejlt.201100231

[7]. AOCS (2020). Official methods and recommended practices of the American oil chemists society. *American Oil Chemists Society*, Champaign, USA.

[8]. Bamgboye, A. I., and Adejumo O. I. (2010). Physicochemical properties of roselle seed oil. *Nutrition & Food Science40*, 186-192 https://doi.org/10.1108/00346651011029219

[9]. Codex Alimentarius Commission (2023). International Food Standards; Recommended standards for edible fats and oils CXS 19-1981 FAO / WHO Rome.

[10]. Ewansiha, C. I., Asia, I. O., Ekebafe, L. O., Jatto, O. E., and Okodugha G. (2011). Proximate and mineral composition of seed shell pericarp of *Chrysophyllum albidum*. *Pacific Journal of Science and Technology 12*, 363-365.

[11]. FDA (2024). Health claim notification for substitution of saturated fat in diet with unsaturated fatty acids and reduced risk of heart disease. Food and Drug Administration https://www.fda.gov

[12]. Gharehbeglou, P., Sarabandi, K., and Akbarbaglu Z. (2024). Insights into enzymatic hydrolysis: Exploring effects on antioxidant and functional properties of bioactive peptides from chlorella proteins. *Journal of Agricultural and Food Research*,*16, 101129*.https://doi.org/10.1016/j.jafr.2024.101129

[13]. Iloamaeke, I. M., Unoka, E. C, Ikezuagu, B. C., and Simon, C. J. (2024). Quality assessment of selected brands of vegetable oil sold at relief market Onitsha, Anambra State of Nigeria. *International Journal of Research and Innovation in Applied Science*,*10*, 317-327.https://doi.org/10.51584/IJRIAS.2024.905029

[14]. Khaled, B. M., Biswas, M., Sina, A. A., Alam, A., Alim, M. A., Hossain, M. E., Sadiq, M. N., Rana M. S., and Sweet, S. R. (2024). Detection of the changes in fatty acid composition and physicochemical properties in selected edible oils heated at different degree of time. *Food Chemistry Advances* *4*, 100716.http://doi.org/10.1016/j.focha.2024.100716

[15]. Mapengo, C. R., Ray, S. S., and Emmambux, M. N. (2022). Granular morphology, molecular structure, and thermal stability of infrared heat-moisture treated maize starch with added lipids. *Food Chemistry*, *382*, 132342.https://doi.org/10.1016/j.foodchem.2022.132342

[16]. Mazzocchi, A., De Cosmi, V., Risé, P., Milani, G. P., Turolo, S., Syrén, M-L., Sala, A. and Agostoni, C. (2021) Bioactive compounds in edible oils and their role in oxidative stress and inflammation. *Frontiers in Physiology*,*12*,659551. https://doi.org//10.3389/fphys.2021.659551

[17]. O'Brien R. D (2017). Fats and Oils: Formulating and processing for applications 3rd Edition CRC Press, Taylor and Francis Group.

[18]. Rajesh, Y., Khan, N. M., Shaikh, A. R., Mane, V. S., Daware, G., & Dabhade, G. (2023). Investigation of geranium oil extraction performance by using soxhlet extraction. *Materials Today: Proceedings*, *72*, 2610-2617.

[19]. Raji, F. A., and AkinosoR. (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*, 1–12. https://doi.org/10.9734/afsj/2019/v13i430116

[20]. Voon, P. T., Ng, C. M., Ng, Y. T., Wong, Y. J., Yap, S. Y., Leong, S. L., Yong,X. S., and Lee, S. W. H.(2024). Health effects of various edible vegetable oils: an umbrella review. *Advances in Nutrition, 15*, 100276.https://doi.org/10.1016/j.advnut.2024.100276

[21]. WenC., Shen, M., Liu, G., Liu, X., Liang, L., Li, Y., . . . Xu, X. (2023). Edible vegetable oils from oil crops: Preparation, refining, authenticity identification and application. Process Biochemistry, 124, 168-179. https://doi.org/10.1016/j.procbio.2022.11.017

[22]. Xiaoping, L., Abubakar, M. A., Yuyue, Z., Ding, L., Blennow, A., and Joerg, F. (2024). Starch phosphorylation regulates starch granule morphological homogeneity in *Arabidopsis thaliana*. *Plant Physiology*,*194*, 2600-2615. https://doi.org/10.1093/plphys/kiad656