Extraction, Physicochemical, Fatty Acid Analysis of *Chrysophyllum Albidum* (African Star Apple) Seed Oil and Nutrient Composition of the Fruit Parts.

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ABSTRACT

In tropical Africa, *Chrysophyllum albidum* fruit is useful as food and also has many industrial applications. In this study, oil was extracted from the seeds of *C. albidum* using normal hexane as the extracting solvent. The average percentage oil recovery using 10g, 20g, 30g, 40g and 50g of thee seed sample was 11.56 % which showed that the seed may not be a good source of abundant oil The physical characterization of the extracted oil showed the density of 0.85 g/ml and pH value of 10.30. The specific gravity of the oil was 0.85 at 20°C which is lower than 0.998 at 20°C, the specific gravity of water indicating that the oil is less dense than water. The oil could be classified as a non-drying oil since its iodine value of 34.00mg/100g was lower than 100. The saponification value was 201.96mg/gKOH. The GC-MS result of the fatty acid composition analysis showed the major fatty acid contained in the oil as palmitic acid, palmitoleic and linoleic acids with percentage weights of 53.97%, 18.40% and 10.25% respectively. The total saturated and unsaturated fatty acid composition were 71.16% and 28.84% respectively. The high percentage of the palmitic acid content of the oil indicated that it could be used as a good substitiute for palm oil in industrial production of products. From the result of the proximate analysis, protein had the least content in the fruit. The C.albidum fruit peel, pulp, seed flesh, seed shell and seed contained 2.45%, 3.15%, 0.50%, 0.98% and 0.23% of protein respectively. The moisture content of the fruit peel, pulp, seed flesh, seed shell and seed were 65.00%, 85.00%, 85.00%, 55.00% and 70% respectively. The high moisture content of the fruit implies that it will have a short shelf life. From the result of the mineral analysis, the C. albidum peel was found to contain all the minerals analysed and in high percentage too. Na content was 8.962ppm, K was 21.565ppm, Ca was 48.587ppm, Mg was 19.240ppm and Fe was 10.539. It is advisable for people to consume the fruit peel rather than discarding it as some. The iron content of the seed shell was the highest while potassium content of the pulp was the highest. Analysis of the peel, pulp and seed flesh confirmed the high average value of 17.37 mg/100g of vitamin C in the fruit.

Keywords: Chrysophyllum albidum, fatty acid profile, proximate, mineral, physicochemical

INTRODUCTION

African star apple is botanically called *Chrysophyllum albidum* and belongs to the sapotaceae family. It is a genus of about 70 – 80 species of tropical trees [1]. The generic name is derived from the Greek words chrysos meaning ‘gold’ and phyllos meaning ‘leaf’ [1]. The Northern South America has the greatest number of species among the tropical regions to which the genus is native throughout the world. The fruit is edible; round, usually yellow skinned (sometimes brownish) often green around the calyx, with a star pattern in the pulp; the flattened 3 – 5 seeds are light brown and hard. The fruit’s skin is chewy like gum and

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contrary to some reports is edible [2]. *C. albidum* fruits are almost spherical, slightly pointed at the tip, about 3.2 cm in diameter, greenish-grey when immature, turning orange-red, yellow brown or yellow sometimes with speckles when ripe. *C. albidum* is widely distributed form West Africa to the Sudan with an eastern limit in kakumega forest Kenya [1]. Its natural occurrence has been reported in diverse ecozones in Nigeria, Uganda, Niger Republic, Cameroon and Cote d' Ivorie [3]. It is distributed throughout southern part of Nigeria. In south west Nigeria, it is called 'agbalumo' and popularly referred to as 'udara' in south eastern Nigeria [4]. The fruit is very popular in the south east especially among pregnant women due to the belief that it aids in delivery. It is known as 'agwaluma' in the northern part of the country although it is not grown there. *C. albidum* is usually available during the month of December to April. The people to which the fruit is native do not normally harvest it but allow it to naturally drop from the tree. It is normally allowed to drop naturally because if it is harvested immature, has a sour taste and is sticky that it can draw the lips together when consumed. To eat the fruit, people first split it open usually by squeezing it between the fingers of both hand, colour of flesh and tears apart not unlike meat [4]. Milky sticky juice drips away when the tasty fruit flesh is directly eaten.

In parts of West Africa, seeds are occasionally collected and their oil extracted for soap making or cooking [5]. *C. albidum* seeds are source of oil, which is used for diverse purposes [5]. The hard seeds of *C. albidum* are stuffed in rattles used by local dancers. Children also use the seeds for local games. The cotyledons of the seeds are used as ointment in treatment of vaginal and dermatological infections in Western Nigeria [6]. The bark and tender leaves of the tree have medicinal applications. Easy to saw and plane, the brownish white wood nails well ,makes a fine polish and is highly sought for construction work, tool handles and much more [2]. Latex can be tapped form the trunk and used as rubber.

Some researchers have previously carried out different analysis on *C. albidum*. Audu *et al*., (2013) extracted and characterized the seed oil of *C. albidum*. It was reported that the acid, peroxide and iodine values were 2.87 mgKOH/g, 1.96 meq/9kg and 33.18 mg/g respectively. They concluded that the iodine value do not suggest high unsaturation and as a result the *C. albidum* oil may find use in the confectionary and biofuels industries since the value is less than 112 gI_2/100g. Ajewole and Adeyeye (1991) reported that *C. albidum* seed oil is rich in both linoleic (36.0 %) and oleic (37.6 %) fatty acids. The fruit has been found to have high content of ascorbic acid with 1000 to 3300 mg of ascorbic acid per 1000g of edible fruit or about 100 times that of oranges and 10 times that of guava or cashew [7]. The fruit also contain 90% anacardic acid, which is used industrially in protecting wood and as a source of resin, while other components of the tree including the roots and leaves are used for medical purposes [5]. Applications of oil extracted from *C. albidum* were investigated by Ajiwe *et al,* in 1997 [8]. Proximate and mineral composition of seed shell pericarp of *C. albidum* was investigated by Ewanisha *et al* in 2011[9]. The use of *C. albidum* seed for the removal of metal ions from aqueous solution was carried out by Oboh *et al*. in 2009 [10]. Chukunda *et al* 2021 carried out an analysis on fungi spoilage and proximate compositions of african star apple *C. albidum* g. don fruits in Port Harcourt metropolis, Nigeria [11]. From their proximate analysis, they found out that the moisture, ash and carbohydrate content of C. albidium were 62.61, 1.21 and 26.30 percent respectively.

This research was aimed at running the physicochemical, proximate, nutrient and mineral analysis of the seed and seed coat of *C. albidium* in addition to the normally consumed parts of the fruit.

Experimental

Sample Collection and Preparation

Fresh fruits of *C. albidum* were picked from the fruit's tree in Okebunoye Village at Alor, Idemili South Local Government Area, Anambra State of Nigeria. It was picked in a large quantity. The fruits were washed and the fruits' peels were separated from the pulp. The fruits' seed flesh were separated from the seed shell. The seed shells were cracked open to separate it from the seed. A large quantity of the seed was

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air dried at room temperature for one week. Different parts of the fruit (peel, pulp, seed flesh, seed shell and seed) were used as samples for different analysis; extraction, physicochemical and nutrient characterization.

PROCEDURE FOR OIL EXTRACTION

Soxhlet extraction method used for this research work. The air dried seeds of *C. albidum* was ground using a thermal willey mill (model 5). 10 g by weight of the ground sample was used. The porous cellulose thimble was weighed and recorded as w_1 and then filled with the ground sample, reweighed and recorded as w_2. The round bottom flask was weighed and recorded as w_3 and was filled with the solvent (normal hexane) up to two thirds of the flask. The reflux condenser was placed on top of the extractor. The condenser was connected to the tap with a hose pipe through the down position for water in let while the top position for water out let was lower down into the sink with a hose pipe. The tap was turned on. The round bottom flask was placed on the heating mantle and the temperature of the mantle adjusted to 65^{o}C. When the solvent refluxed over the barrel three times, the condenser was detached and the thimble removed. The extraction was repeated with 20 g, 30 g, 40 g and 50 g weight of sample. Each extraction was performed for 3 hours. The extract was put in a rotary solvent evaporator. The solvent was recovered and the oil concentrate remained. The round bottom flask containing only the seed oil was weighed and recorded as w_4. The percentage of the oil recovery was determined as shown below

$$\textbf{\% oil yield} = \frac{weight\ of\ sample\ before\ extraction - weight\ of\ sample\ after\ extraction}{weight\ of\ sample\ before\ extraction} \times \frac{100}{1}$$

Characterization of the Extracted Oil

In evaluating the quality of the extracted oil, the physical and chemical analyses of the oil were carried out.

Physical Analysis of the Extracted Oil. Density/Specific gravity

50nm pycnometer bottle was washed thoroughly with detergent water and petroleum ether. The bottle was dried and weighed (w_1) with an electronic balance. The bottle was filled with water and reweighed (w_2). It was dried again. After drying the bottle, it was filled with the oil sample and weighed (w_3). The specific gravity and density were calculated as shown below

$$\text{Specific gravity} = \frac{weight\ (ml)\ of\ \ oil}{weight\ (ml)\ of\ water} = \frac{w_3 - w_1}{w_2 - w_1}$$

pH

pH was measured by electrometric method using laboratory pH meter Hanna model H1991300 [12]. The electrodes of the pH meter were rinsed with distilled water and dried. It was rinsed in a small beaker with a portion of the sample. Sufficient amount of the sample was poured into a small beaker to allow the tips of the electrodes to be immersed to a depth of about 2 cm. The electrode was at least 1cm away from the sides of the beaker. The meter was turned on and the pH of the sample was recorded.

Chemical Analysis of the Extracted Oil Determination of acid value

25 cm^3 of diethyl ether and 25 cm^3 of ethanol were mixed in a 250 cm^3 beaker and was added to 10 g of oil in a 250 cm^3 conical flask. Two drops of phenolphthalein were added to the mixture. The mixture was titrated with 0.1 M NaOH. A dark pink colouration was observed at end point. The acid value was calculated as shown below

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Acid value = $\frac{titre(ml) \times 5.61}{weight\ of\ sample\ used}$

The free fatty acid figure is usually calculated as oleic acid (1 cm^3 of 0.1 M NaOH = 0.0283 g of oleic acid). The free fatty acid (FFA) = (acid value)/2.

Determination of iodine value

0.5 g of the oil was weighed out using an electronic balance by transferring a suitable quantity into a dry glass bottle of 250 cm^3 capacity using a glass rod. 10 cm^3 of carbon tetrachloride was added to the oil and was allowed to dissolve. 20 cm^3 of Wiji's solution was added and the stopper (previously moistened with potassium iodine solution) was used to cover it and allowed to stand in the dark for 30 minutes. After 30 minutes, 15 cm^3 of 10 % potassium iodide solution and 100 cm^3 of distilled water were added and the solution mixed together. The solution was titrated with 0.1 M thiosulphate solution using starch as indicator till the end point where blue-black colouration becomes colourless. A blank titration was carried out at the same time. The iodine value was calculated as below.

Iodine value = $\frac{(b-a) \times 1.269}{weight(g)\ of\ sample}$ where b = blank titre

value,

a = sample titre value.

Determination of saponification value

2 g of the oil was weighed into a 250 cm^3 conical flask and 25 cm^3 of ethanoic potassium hydroxide solution (prepared by dissolving 5 g of KOH in 1 litre of ethanol) was added. The mixture was boiled gently under reflux on a water bath for 1 hour with frequent shaking. After boiling, the hot excess alkali was titrated immediately with 0.5 M HCl using 1cm^3 of phenolphthalein solution as indicator. A faint pink colouration indicated the end point. A blank titration was carried out at the same time and the saponification value was calculated as shown below.

Saponification value = $\frac{(b-a) \times 28.05}{weight(g)\ of\ sample}$

where b = blank titre value, a = sample titre value.

Determination of peroxide value.

1 g of the oil was weighed into a clean dry boiling tube. 1 g of powdered potassium iodide and 20 cm^3 of solvent mixture (2 vol. glacial acetic acid + 1 vol. chloroform) were added to the boiling tube. The tube was placed in boiling water and the liquid was allowed to boil vigorously for 30 seconds. The hot solution was transferred into a flask containing 20 cm^3 of 5% potassium iodide solution. The tube was washed out twice with 25 cm^3 of distilled water. The solution was titrated with 0.002 M sodium thiosulphate ($Na_2S_2O_3$) solution using 1 cm^3 of starch as an indicator. A blank titration was performed at the same time. The peroxide value was calculated as shown below.

Peroxide value = $\frac{2 \times titre\ value}{weight\ of\ sample}$

GC-MS ANALYSIS FOR FATTY ACID.

The extracted oil was converted to methyl esters using the method described by Akintayo and Bayer, 2002 [13]. 1 g of the oil was treated with 10 cm^3 sodium methoxide under reflux for 1 hr. 10 cm^3 of distilled

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water in 1 M methanol was added followed by 3-4 drops of conc. H_2SO_4. The methyl esters of the oil were removed by evaporation. Finally the water present in the oil was removed by treating the oil with anhydrous sodium sulphate. The fatty acid methyl esters were analyzed using a GC-MS powered with HP chemsitation Rev. a 0901(1206) software fitted with flame ionization detector and a computing integrator. Nitrogen was used as a carrier gas. The column initial temperature was 250 $^{\circ}$C rising at 5 $^{\circ}$C/min to a final temperature of 310 °C and 350 °C respectively. A polar (HP INNO wax capillary column (30 x 0.53 x 0.25 micrometer) was used to separate the esters. The esters of the fatty acids were identified by comparison of retention times of the oil components with those of standard methyl esters. By using the standard mixture of FAME (Sigma, St. Louis MO, USA) calibration curves were generated and used for the quantification of the methyl esters of the oil present in the sample.

Proximate Analysis

The crude protein, crude fat, ash, moisture crude fiber and carbohydrate content of *C. albidum* peel, pulp, seed flesh, seed shell and seed were determined using standard methods [14].

Determination of crude protein

1 g of the sample was carefully weighed into a 30 cm^3 kjehdal flask to prevent the sample from touching the walls of the flask. 1 g of the kjedahl catalyst mixture (hot conc.H_2SO_4 and a tablet of selenium catalyst) was added. The flask was closed with a cork and shaken. The mixture was heated using a heating mantle in a fume chamber until a clear solution was obtained. It was allowed to stand for 30 minutes to cool. After cooling, 100 cm^3 of distilled water was added to avoid caking and then transferred to the kjedahl digestion apparatus. A 500 cm^3 receiver flask containing 5 cm^3 of boric acid indicator was placed under a condenser of the distillation apparatus so that the condenser's delivery tube was about 2 cm^3 inside the solution. The 10 cm^3 of 40 % NaOH was added to the digested sample on the apparatus and distillation commenced immediately until the distillate reached the 35 cm^3 mark of the receiver flask after which it was titrated to pink colour using 0.01 M hydrochloric acid. The percentage crude protein was calculated as shown below.

% crude protein = % Nitrogen x 6.25

% Nitrogen = Titre value x dilution factor x atomic number of nitrogen x normality of acid.

where 6.25 = protein constant.

Determination of crude fat

2 g of the sample, 100 cm^3 of chloroform and 50 cm^3 of methanol were weighed and added inside a capacity flask of weight w_1. The mixture was left for 24 hours and then filtered. The residue was washed with a mixture of chloroform and methanol. The filtrate was introduced into a separating funnel and water added. The lower chloroform layer was separated into the 250 cm^3 capacity flask and evaporated to dryness. After cooling in a desiccator, the flask was reweighed w_2. The fat content was calculated as shown below.

$$\textbf{Fat} = \frac{W_2 - W_1}{Weight\%\ of\ sample} \times \frac{100}{1}$$

where W_1 = weight of empty bottle.

W_2 = weight of bottle + residue.

Determination of ash content

Empty platinum crucible was washed, dried and weighed (w_1). 5 g of the wet sample was weighed into the

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platinum crucible (w_2) and placed in a muffle furnace at 600^{o}C for 3 hours. The sample was cooled in a desiccator after burning and was weighed (w_3). The ash content was calculated as shown in below.

% Ash content = $\frac{W2-W1}{W_3-W_1} \times \frac{100}{1}$

W_1 = weight of empty platinum crucible

W_2 = weight of platinum crucible and sample before burning

W_3 = weight of platinum crucible and ash.

Determination of moisture content

An empty petri dish was washed and dried in an oven for about 10 minutes and allowed to cool in a desiccator containing calcium chloride for about 20 minutes and then weighed (w_1). 2 g of the sample was weighed into the petri dish (w_2) and placed in an oven at 105^{0}C. It was then brought out, cooled in a desiccator and weighed (W_3). The procedure was repeated until a constant weight was obtained.

% Moisture content = $\frac{w2-w3}{w_2-w_1} \times \frac{100}{1}$w $_1$ = weight of

empty petri dish

w_2 = weight of empty petri dish and sample before drying.

w_3 = weight of petri dish and sample after drying.

Determination of crude fiber

2 g of the sample was weighed into a 500 cm^3 beaker. The content was boiled for 30 minutes in the presence of pre-heated 200 cm^3 of 1.2 % sulphuric acid. The mixture was filtered and the residue washed 3 times with hot water. 200 cm^3 of 1.25 % hot NaOH was poured into the filterate and boiled and drops of 1 – octanol (antifoaming agent) was added and boiled slowly again for another 30 minutes, filtered and washed 3 more times with hot water. Then acetone was used in washing the sample 3 times. The residue was transferred to a crucible and was dried at 130 $^\circ$C in an oven to a constant weight. It was transferred to a furnace for ashing at 500 $^\circ$C. Then the ash was weighed and the weight of fiber calculated from the difference as shown below.

% Crude fibre = $\frac{w2-w3}{weight\ of\ sample} \times \frac{100}{1}$

where w_2 = weight of crucible + sample after washing and drying in an oven.

w_3 = weight of crucible + sample ash

Determination of carbohydrate content

Total sum of percentage crude protein, crude fat, crude fiber, moisture and ash content was subtracted from 100 % dry weight of each sample to obtain available carbohydrate as the Nitrogen free extractive (NFE) as shown below

% NFE = 100 – % (a + b + c + d + e)

Where a = protein, b = fats, c = fibre, d = ash, e = moisture.

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Calculation of energy value.

Energy value of *C. albidum* was calculated using the formula as described by Chancy, 2006 as shown below.

Energy = % protein x 4 + % fat x 9 + % carbohydrate x 4 [15].

Determination of Vitamin C

5 g each of the samples was homogenized in 6 % EDTA/TCA solution. The homogenate was filtered and used for analysis. 20 cm^3 of 30 % KI solution was added to the homogenate followed by 100 cm^3 of distilled water. 1 cm^3 of 1 % starch solution was added to it and it was titrated against 0.1 M $CuSO_4$ solution. There was a black colouration at end point and the vitamin C content was calculated as shown below.

$$\textbf{Vitamin C} = \frac{100 \times 0.88\,(titre - blank)}{weight\ of\ sample}$$

Determination of Elemental Composition

Mineral element analysis was conducted using varian AA240 Atomic Absorption Spectrometer (AAS) according to the method of American Public Health Association [12]

Working principle: Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Procedure

The method of APHA 1995 was adopted. Samples were dried at 45°C in an oven for 1hour. After drying, the individual samples were crushed into fine powder using mortar and pestle, and 2 g of the fine powdered sample was weighed into a porcelain crucible. The samples were then heated at 400°C for 4 hours in a muffle furnace. It was removed after 4 hours from the furnace and allowed to cool in a desiccator. 0.5ml of 1M trioxonitrate (V) acid (HNO_3) solution was added to the left-over ash and evaporated to dryness on a hot plate and returned to the furnace for heating again at 400^0c for 15 – 20 minutes until perfect grayish – white ash is obtained. The samples were allowed to cool in a desiccator. 15 cm^3 of hydrochloric acid (HCl) was added to the ash to dissolve it and the volume made to the100 cm^3 with distilled water. The solution was filtered into a 100 cm^3 volumetric flask. The volume was made up to 100 cm^3 with distilled water.

RESULTS AND DISCUSSION

Table 1 Oil extraction

Weight of thimble (g)	Weight of sample (g)	Weight of thimble + sample before extraction (g)	Weight of thimble + sample after extraction (g)	% Oil recovery
2.42	10.00	12.42	11.39	10.30
2.42	20.00	22.42	20.14	11.40
2.42	30.00	32.42	28.85	11.90

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2.42	40.00	42.42	37.62	12.00
2.42	50.00	52.42	46.32	12.20

The yield of oil was based on the weight (g) of the sample before extraction as shown in Table 1. It was observed that the more the weight (g) of sample used for extraction the greater the percentage yield of oil. For 10 g weight of sample, the oil yield was 10.30 % while for 50 g weight of sample; the oil yield was 12.20 %. The average oil recovery of *C. albidum* seed was 11.56 %. The result of the oil recovery of *C. albidum* seed reported in this study was low compared to the values reported earlier in seeds of neem 46 %, cotton 24 % and groundnut 46 % [16]. According to Akpuaka and Nwankwor, 2000, the oil recovery of *C. albidum* was also lower than 48-52 % obtained for *Tetracarpidium conophorum* [17]. This indicated that *C. albidum* may not be a good source of abundant oil. However, genetically modified breeds may be developed which could produce seeds with higher oil recovery. Adebayo *et al.*, 2012 earlier reported 10.80 % oil recovery for *C. albidum.*

Table 2 Physical characteristics of the extracted oil from *C. albidum* seed

Characteristics	**Value**
Density	0.85g/mL at 20°C
Specific gravity	0.85 at 20^{o}C
pH value	10.30
Odour	Inoffensive

Table 2 showed the physical characteristics of the extracted *C.* albidum seed oil. The oil had a density of 0.85g/ml at 20°C which showed that it was less dense than water. This value was close to 0.75g/ml at 20 $^{\circ}$C obtained by Belewu *et al*., 2010 and Tint and May, 2009 for *Jatropha curcas* seed oil [19][20]. The specific gravity obtained at 20 $^{\circ}$C for *C.* albidum seed oil was 0.85 which was close to 0.877 and 0.89 at 20 $^{\circ}$C earlier reported by Agbede *et al.*, 2012 and Adebayo *et al* 2012 respectively [21][18]. This value was lower than 0.998 at 20 $^{\circ}$C which is the specific gravity of water. This showed that this oil was less dense than water [22]. The specific gravity of oils generally characterizes the fluidity of oils in automobile engines and the value obtained in this study was close to the range 0.87 – 0.90 acceptable for biodiesel [23].The pH value of the oil was 10.30 as shown in Table 2, which was higher than 5.27 pH value of the same *C.* albidum seed oil earlier reported by Agbede *et al*., 2012.

Table 3 Chemical characteristics of the extracted oil from *C. albidum* seed.

Characteristics	**Value**
Acid Value	5.63 mg/gKOH
Free fatty acid	2.82 mg/gKOH
Iodine Value	34.00 mg/100g
Saponification value	201.96 mg/gKOH
Peroxide value	4.20 meq/gKOH

Table 3 showed the chemical characteristics of oil extracted from *C. albidum* seed. The acid and free fatty acid obtained in this study as shown in Table 4.3 were 5.63 mg/gKOH and 2.82 mg/gKOH which were higher than 3.56 mg/gKOH and 1.76 mg/gKOH obtained by Akubugwo and Ugbogwu, (2007) for *C. albidum* oil but compared favourably with 4.50 mg/gKOH and 2.25 mg/gKOH obtained for the same fruit by Adebayo *et al.*, (2012). The acid value of 5.63 mg/gKOH obtained in this study was higher than 1.19 mg/gKOH obtained by Afolayan *et al.*, (2014) for groundnut oil and 1.23 mg/gKOH obtained by Morvarid

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et al., (2013) for palm oil. Acid value is used as an indicator for edibility of oil and suitability for use in paintindustry [24]. Acid value is an important chemical property of oil which is used to determine the quality, age, edibility, suitability of oil for industrial use such as paints etc. This value is used to measure the extentof glycerides in the oil which have been decomposed by lipase and other physical factors eg. heat. It is common knowledge that these parameters are measures of the level of spoilage of oil. The presence of FFA in an oil or fat is an indication of previous lipase activity, other hydrolytic action or oxidation [25].The lowvalue of both acid and free fatty acid confirmed the freshness and edibility of the oil. The iodine value 34 mg/100g reported in this work as shown in Table 3 was in close agreement with the 31.86 mg/100g , 33.18 mg/100g and 33.12 mg/100g from previous works on *C. albidum* by Akubugwo and Ugbogwu, (2007), Audu *et al.*, (2019) and Adebayo *et al*., (2012) respectively. The iodine value is used to quantify the amountof double bonds in an oil which reflects its susceptibility to oxidation [26]. Since the iodine value of *C. albidum* seed oil was lower than 100, it could be classified as non-drying oil. The low iodine value indicatedthat the oil had a low content of unsaturated fatty acids thus resembles olive oil and groundnut oil. It could be employed for manufacture of soaps, lubricating oils and lighting candles which traditionally require fatsor saturated oils [27]. Thus the oil will not attract high interest in the paint and coating industry unless it undergoes dehydration before use [28]. This oil could be an alternative for the manufacture of some products that have previously depended on edible. The saponification value obtained was 201.96 mg/gKOH which compared favourably with values obtained for some common oils like palm oil (196–205 mg/gKOH), ground nut oil (188–196 mg/gKOH), corn oil (181–196 mg/gKOH) and palm kernel oil (247 mg/gKOH/) asreported by Pearson, (1976). Saponification value is an index of average molecular mass of various fatty acids in the samples. The lower value of saponification means molecular weight of fatty acid was lower andhas lower limit of use in industry. The saponification value of 201.96 mg/gKOH obtained for *C. albidum* seed oil in this study was close to 201.4 mg/gKOH obtained for ground nut oil by Musa *et al.,* (2012). This showed that the oil might have a potential for use in soap making and cosmetics industry and for the thermal stabilization of poly vinyl chloride [29]. However, this saponification value was within the range for edible oils outlined by Eromosele *et al.,* (1994). The peroxide value in this study as shown in Table 3 was 4.20 meq/gKOH, which was higher than 1.57 meq/gKOH earlier reported by Adebayo *et al*., (2012). Peroxidevalue gives an indication of the primary oxidation state of oil. The test is based on the ability to liberateiodine from potassium iodide. Fresh oils have values less than 10 meq/gKOH. Higher values between 20and 40 result to a rancid taste [24]. The peroxide value of 0.88 meq/gKOH obtained for palm oil by Yousefi *et al* (2013) and 0.56 meq/gKOH obtained for coconut oil by Sulaiman *et al*., (2012) are lower than 4.20meq/gKOH obtained for *C. albidum* in this study.

Table 4 Fatty acid composition of *C. albidum* seed oil.

Fatty acid	Profile	% Weight
C_{15}	Pentadecyclic	1.83
$C_{16:1}$	Palmitoleic acid	18.40
$C_{16:0}$	Palmitic acid	53.97
C_{10}	Capric acid	0.49
C_{11}	Undecyclic acid	3.38
C_{12}	Lauric acid	3.54
C_{14}	Myristic acid	1.92
C_{17}	Margaric acid	1.47
$C_{18:2}$	Linoleic acid	10.25
$C_{18:3}$	Linolenic acid	0.19
C_{18}	Stearic acid	4.56

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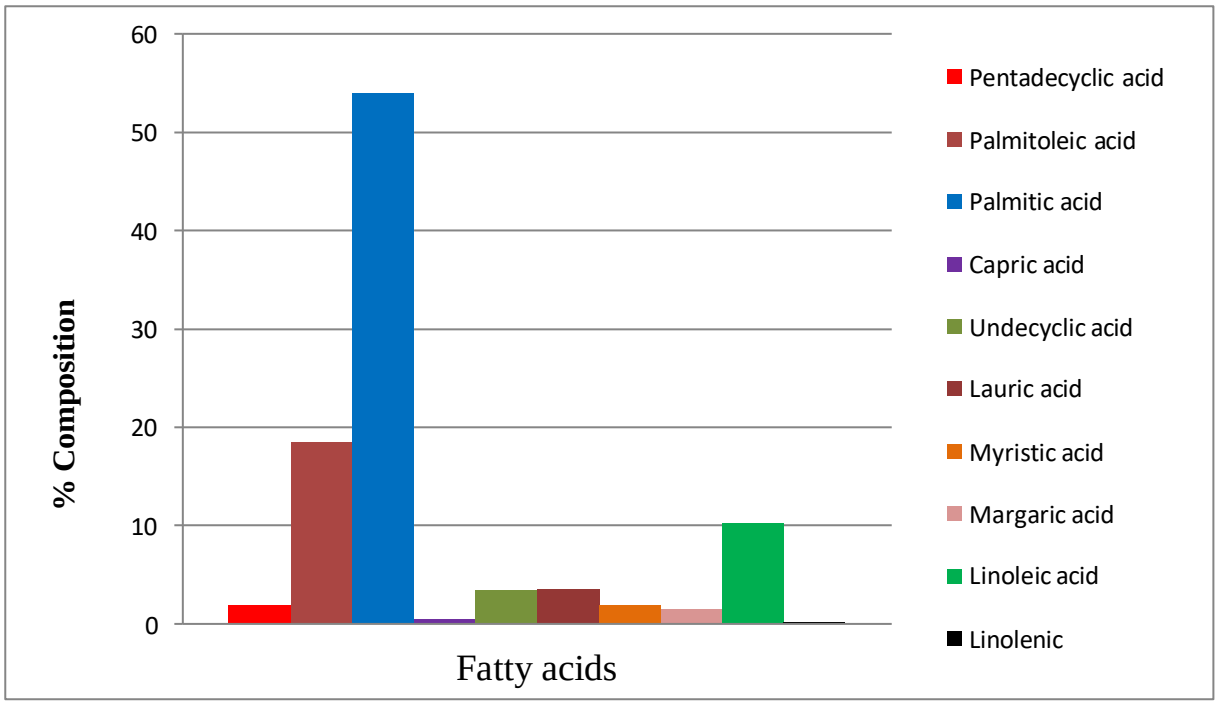

Figure 1 Fatty acid composition of *C. albidum* seed oil.

The major fatty acids present in the seed oil extract of *C. albidum* and the percentage composition was presented in Table 4 and Figure 1. The major fatty acids present as shown in Table 4 are palmitic acid 53.97 %, palmitoleic 18.40 % and linoleic acids 10.25 %. The total saturated fatty acid composition of the oil was 71.16 % while the total unsaturated fatty acid composition was 28.84 %. Oils in the diet are available to the body as fatty acids which are excellent sources of dietary calorie intake [30]. This was lower than 92.92 % saturated fatty acid and 7.12 % unsaturated fatty acid of coconut oil obtained by Chowdhury *et al.*, (2007). The 53.97 % palmitic acid of *C. albidum* obtained in this work was higher than 44 % palmitic acid of palm oil and lower than 8.8 % palmitic acid of coconut oil obtained by Sulaiman *et al.*, (2012). The 28.84 % of the total unsaturated fatty acid composition obtained in this study did not agree with 72.15 % unsaturated fatty acid of *C. albidum* reported by Adepoju *et al.*, (2013) but confirmed the low iodine value obtained in this work. Chowdhury *et al.*, (2007) reported that palm oil contains 41.78 % palmitic acid which was lower than 53.97 % palmitic acid obtained for *C. albidum* seed oil in this study. Ajewole, (1991) reported that the *C. albidum* seed oil was rich in both linoleic 36 % and oleic 37.6 % fatty acids. This was contrary to that reported in this work. This difference might be due to the geographical area and soil composition.

Table 5 Proximate composition of *C. albidum*

Sample (Percentage %)

Nutrients	Peel	Pulp	Seed flesh	Seed shell	Seed	Average
Crude protein	2.45	3.15	0.50	0.98	0.23	1.46
Crude fat	10.00	2.00	6.00	12.00	11.56	8.30
Ash	1.00	6.00	2.50	8.50	4.85	4.57
Moisture	65.00	85.00	85.00	55.00	70.00	72.00
Crude fiber	5.00	1.00	5.00	14.97	4.20	6.03
Carbohydrate	16.55	2.85	1.00	8.55	9.16	7.62
Energy(kcal)	166.00	42.00	60.00	146.00	107.05	104.21

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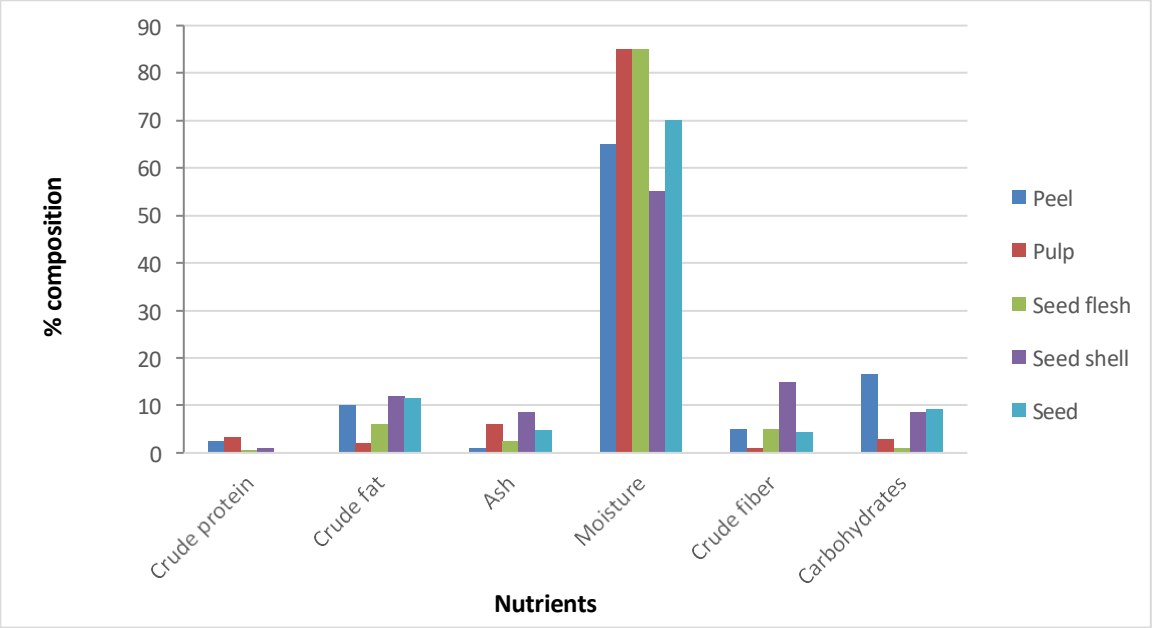

Figure 2 Proximate Composition of *Chrysophyllum albidum.*

The protein content of *C. albidum* peel, pulp, seed flesh, seed shell and seed were 2.45 %, 3.15 %, 0.50 %, 0 98 % and 0.23 % respectively as shown in Table 5. The 3.15 % protein content of the pulp obtained in this work was close to the 3.90 % obtained for the same fruit part by Adepoju *et al.*, (2012) as well as 3.85 % obtained by Ibrahim *et a*l., (2021). These results showed that *C. albidum* was low in its protein content. This value could be improved by the dehydration of the fruit [31]. The fat content as shown in Table 5 of *C. albidum* peel, pulp, seed flesh, seed shell and seed were 10.00 %, 2.00 %, 6.00 %, 12.00 % and 11.56 % which differ from 8.94 %, 10 %, and 3.45 % earlier reported for the peel, pulp and seed of *C. albidum* by Edem and Mirinda (2011). This could be as a result of the geographical area of the fruit tree. The fat content of *C. albidum* seed obtained in this study was close to 11.70 % crude fat content reported for the pulp of *Averrhoa carambola* fruit (Edem and Mirinda, 2011).The ash content as shown in Table 5 for *C. albidum* peel, pulp, seed flesh, seed shell and seed were 1.00 %, 6.00 %, 2.50 %, 8.50 % and 4.85 %. The moisture content of the *C. albidum* peel, pulp, seed flesh, seed shell and seed as shown in Table 5 were 65.00 %, 85.00 %, 85.00 %, 55.00 % and 70.00 % respectively which are higher than 47.95 %, 32.65 % and 26.55 % earlier reported for the fruit's peel, pulp and seed by Edem and Mirinda (2011). Adepoju *et al.*, (2012) reported that the pulp of *C. albidum* contained 76.30 % moisture content which was close to 85.00 % obtained in this study. The moisture content of the whole *C. albidum* fruit had the greatest value as shown in Figure 2. The moisture content of any food is an index of its water activity [32] and is used as a measure of the stability and susceptibility of microbial contamination [33]. Its implication is that *C. albidum's* shelf life would be short due to its high moisture content. The high moisture content also implied that dehydration would increase the relative concentrations of other food nutrients and improve the shelf life of *C. albidum* [31]. The fiber content of *C. albidum* peel, pulp, seed flesh, seed shell and seed were 5.00 %, 1.00 %, 5.00 %, 14.97 % and 4.20 % respectively as shown in Table 5. The 5.00 % fiber content of the fruit's peel was close to 4.50 % earlier reported for the *C. albidum* peel by Amusa *et al.*, 2003. The fruit's seed shell had the highest fiber content as shown in Figure 2. The crude fiber content of the fruit could be increased by the dehydration of the fruit [34]. The consumption of fruits with high crude fiber content may contribute to a reduction in the incidence of certain diseases like colon cancer, coronary heart diseases, diabetes, high blood pressure, obesity and other digestive disorders. Increased crude fiber consumption also increase fecal bulk and rate of intestinal transit and have prebiotic effects [31]. The carbohydrate content obtained for *C. albidum* peel, pulp, seed flesh, seed shell and seed were 16.55 %, 2.85 %, 1.00 %, 8.55 % and 9.16 % respectively. The carbohydrate content of the fruit pulp 2.85 % did not agree with 78.34 % earlier reported

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for the same fruit part by Edem and Mirinda, (2011). The average energy value of *C. albidum* obtained in this study was 167.80 kcal/100g as shown in Table 5 and Figure 2 which was slightly lower than 193.6 kcal/100g earlier reported by Adepoju *et al.*, (2013). Table 5 showed that the *C. albidum* peel had the highest energy value of 166.00 kcal while the fruit pulp had the least energy value of 42.00 kcal. The 42.00 kcal energy value obtained in this study is lower than 99.92 kcal earlier reported for the same fruit part by Ureigho and Ekeke, (2010). This could be as result of the composition of the soil where the tree from which the fruit was picked germinated.

Of all the parts of the *C. albidum* fruit analysed (peel, pulp, seed flesh, seed shell and seed) moisture had the highest percentage content as it can be seen from the bars in Figure 2. Crude protein had the least content. This showed that any time the fruit is consumed, one gets moisture in the highest percentage of all the nutrients.

table 6 Vitamin C content of *C. albidum*.

Sample (mg/100g)

Nutrient	Peel	Pulp	Seed flesh
Vitamin C mg/100g	15.36	17.5	19.26

The vitamin C content of *C. albidum* peel, pulp and seed flesh as presented in Table 6 were 15.36 mg/100g, 17.50 mg/100g and 19.26 mg/100g respectively. The seed flesh of *C. albidum* fruit was found to contain the highest amount of vitamin C. As a result, it is advisable that one should consume the peel together with the pulp. The vitamin C composition in these three parts of the fruit confirmed why these parts are the edible portions of the fruit. From the results of Ige and Gbadamosi in 2007 the vitamin C content of C. albidum fruit juice was 49.4 mg/100 L. Dauda in 2013 obtained a vitamin C content of 12 mg/100 g for C. albidum fruit juice which is close to that obtained for the peel of C. albidum in this work. Abolaji and Adiaha (2015) obtained the vitamin C content of 173.77mg/100g for the fruit pulp and 107.33mg/100g for the peel of *C. albidum* fruit on day one after the harvest. The high ascorbic acid content of the fruit was believed to contribute greatly to the acidic taste of the fruit, especially when it is not fully ripe and soft [35]. This showed that the fruit is rich in vitamin C and would be a good immune booster when adequately consumed. It would help to prevent scurvy, heart disease, high blood pressure, common cold, skin cancer, asthma. dry and splitting hair, gingivitis (inflammation of the gums), bleeding gum, rough dry scaly skin, decreased wound-healing rate, easy bruising; nose bleeding and decreased ability to ward off infection. Asare *et al* (2015) reported some exotic fruits vitamin C content such as grape fruit 56 mg/100 L, pawpaw 53 mg/100 g, sweet orange 31 mg/100 g, mango 34.7 mg/100 g and tomato 27 mg/100 g. These fruits have higher content of vitamin C when compared to *C. albidum* from the results obtained in this work.

Table 7 Mineral composition of *C. albidum*

Concentration (ppm)

Elements	**Peel**	**Pulp**	**Seed flesh**	**Seed shell**	**Seed**
Sodium	8.962	8.853	8.631	8.152	9.395
Potassium	21.565	21.814	18.356	1.175	4.257
Calcium	48.587	40.252	38.910	35.495	31.757
Magnesium	19.240	19.273	18.771	15.571	17.884
Iron	10.539	10.122	10.068	11.025	8.174

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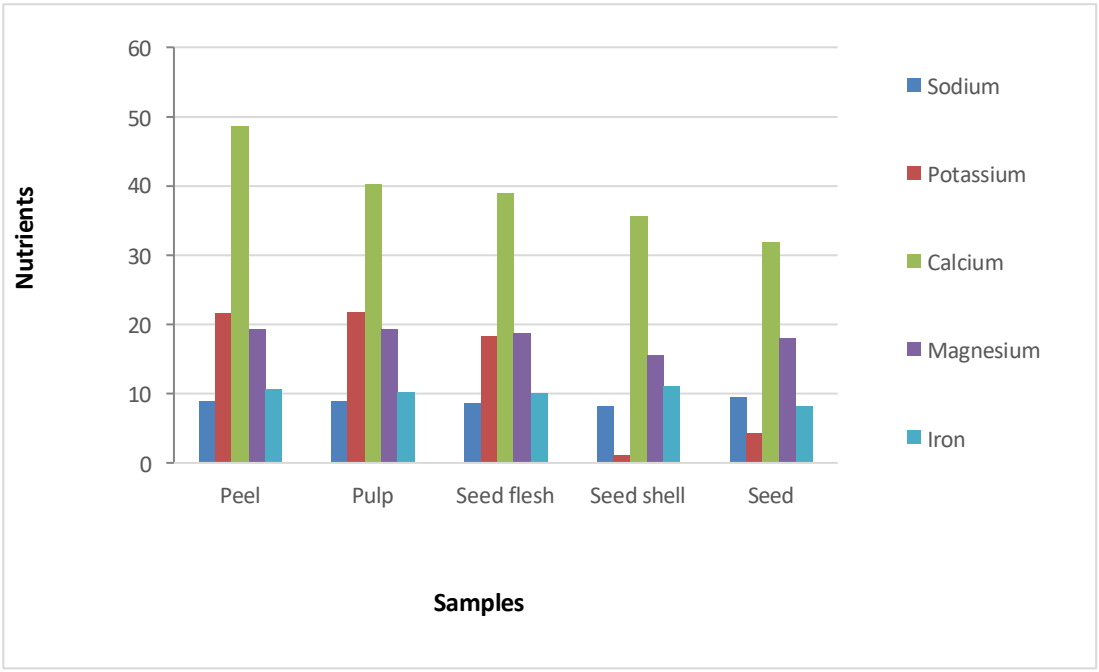

Figure 3: Mineral composition of *C. albidum*

The sodium content of *C. albidum* peel, pulp, seed flesh, seed shell and seed as shown in Table 7 were 8.962, 8.853, 8.631, 8.152 and 9.395 ppm respectively. The sodium content of the fruit's seed was the highest according to the result shown in Table 7. Ukana *et al.*, 2012 reported 37.516 mg/kg for the fruit seed. Sodium is the principal extracellular cation and is used for acid-base balance and osmoregulation in inter modular fluid. The potassium content presented in Table 7 showed that the peel, pulp, seed flesh, seed shell and seed of *C. albidum* contained 21.565, 21.814, 18.356, 1.175 and 4.257 ppm. From these results, the pulp of the fruit had the highest potassium content while the seed shell had the least content. Potassium is the principal cation in intracellular fluid and functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle, cell membrane function [36]. The calcium content obtained in this research work as reported in Table 7 showed that the peel, pulp, seed flesh, seed shell and seed of *C. albidum* contained 48.587, 40.252, 38.910, 35.495 and 31.757 ppm. These results showed that the peel had the highest calcium content while the seed had the least calcium content. The 40.252 ppm calcium content of the fruit's pulp obtained in this work corresponded to the 40.996 mg/kg reported by Ukana *et al.*, (2012) for the same fruit pulp. The calcium values of the fruit suggested the usefulness of the *C. albidum* to pregnant women. The magnesium content of the *C. albidum* peel, pulp, seed flesh, seed shell and seed as shown in Table 7 were 19.240, 19.273, 18.771, 15.571 and 17.884 ppm. These results showed that the pulp of the fruit had the highest magnesium content while the seed shell had the least magnesium content. The iron content of *C. albidum* peel, pulp, seed flesh, seed shell and seed were 10.539, 10.122, 10.068, 11.025 and 8.174 ppm respectively as shown in Table 7. These results showed that the seed shell of the fruit had the highest iron content while the seed had the least content. Iron is one of the most abundant metals on earth. It is ranked as the ninth most abundant metal [37] and is used in a variety of ways. For example iron (III) chloride is used as a coagulant in the treatment of water and waste water especially in the removal of heavy metals and particles. The mechanism of this reaction is that when in solution, it forms the hydroxide for example $Fe(OH)_3$. This is one of the relevance of seed shell of *C. albidum* as a coagulant in the treatment of water and waste water [38].

Figure 3 confirmed that calcium had the highest content as it could be seen that of all the parts of the *C. albidum* fruit analysed (peel, pulp, seed flesh, seed shell and seed) calcium had the most outstanding bar in the chart followed by magnesium. This means that no matter the part of the fruit one decides to consume,

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he/she gets calcium in the highest percentage.

CONCLUSION

The oil recovery of *C. albidum* seed obtained in this study was low which showed that the fruit may not be a good source of abundant oil. The physical and chemical properties of the seed oil compared favourably with those obtained by earlier researchers. From the fatty acid composition analysis it was noticed that *C. albidum* was composed chiefly of palmitic acid which was even more in percentage than that found in palm oil. This means that *C. albidum* seed oil could be used as a good substitiute for palm oil in industrial production of products. The proximate analysis result showed that the fruit had high moisture content and will easily lose viability when stored over a long period of time. Its mineral analysis showed that it is a good source of calcium while its seed shell was rich in iron

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