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Assessing the oil yield and physicochemical parameters of the seed oil of *Chrysophyllum albidum* (African Star Apple)

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Abstract

Chrysophyllum albidum is of great economic value in tropical Africa due to its diverse industrial, medicinal, and food uses. In Ghana, the fruit is locally known as "Alansa," but its full potential has not been fully explored. In this study, oil was extracted from the seeds of *Chrysophyllum albidum* (Africa Star Apple) fruit using two methods: Soxhlet extraction and maceration, with normal hexane as the extraction solvent. The extraction was conducted at a temperature of 65 °C for the Soxhlet extraction method. The aim of these methods was to determine the percentage oil yield. The results showed that the oil content was 2.13% by Soxhlet extraction and 1.24% by maceration. Characterization was performed to determine the physical and chemical properties of the extracted oil. The results revealed that the oil was yellow in colour, with no offensive smell. It had a specific gravity of 0.94 kg/m3, saponification value of 181.203 mg/KOH/g, iodine value of 126.6804 mg/g oil, acid value of 5.52%, free fatty acids value of 2.77%, peroxide value of 4.50 meq/kg, and refractive index of 1.3648 at 20 °C. These findings suggest that *Chrysophyllum albidum* seeds may not be a highly productive source of oil based on their oil yield. However, the studied characteristics of the extracted oil indicate that it may still hold economic value in Ghana.

Keywords: *Chrysophyllum albidum*; drying; extraction; oil yield; physicochemical properties

1. Introduction

Seeds have been extensively utilised as a valuable source of nourishment for both humans and animals, owing to their nutrient-rich composition essential for plant growth. Seed-based foods, including cereals, legumes, and nuts, form a substantial part of the human diet. Plant seeds have been exploited since ancient times as a reliable source of vegetable oil and fat. Certain plant seeds, such as soybeans, cotton seeds, groundnuts, corn palm seeds, and sunflower, have traditionally been commercially cultivated for their oil content, as documented [1]. Many of these seeds possess not only significant oil content but also high protein content. The by-product or residue remaining after oil extraction often serves as animal feed, further enhancing the utilisation of these seeds, as highlighted [2].

Plant-derived fats and oils contribute to approximately three-fifths of global consumption, while the remaining portion is sourced from animals and marine sources, as stated [3]. Chemically, fats and oils consist of triglycerides, distinguishing them from waxes, which lack glycerine in their structure. Fats primarily consist of saturated fatty acids, while oils are predominantly composed of unsaturated fatty acids. Although various plant parts may yield oil, it is primarily extracted from seeds of plants growing in diverse regions worldwide. Oil seeds are commonly pressed to obtain highly nutritious oils. Seeds are known to be rich in unsaturated fats and, when consumed in moderation, are considered a healthy food choice. However, it should be noted that not all seeds are suitable for consumption [2].

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In recent decades, vegetable oils have gained increasing attention as a preferred alternative to petroleum or mineral oil, primarily due to environmental concerns associated with the latter. Mineral oil is a significant contributor to volatile organic compounds (VOCs), which pose persistent pollution problems threatening the ecosystem [4].

Chrysophyllum albidum, a member of the Sapotaceous family, is a tree species ranging from small to medium-sized, and it thrives in diverse eco-zones across Africa. This remarkable plant holds significant economic potential due to its various applications in industries, medicine, and food. While it has been commercially valued in Nigeria, its presence in Ghana remains relatively unknown. The large berries of *Chrysophyllum albidum* are renowned for their high iron and vitamin C content, as well as the abundance of unsaturated fatty acids. Previous studies have revealed that the seeds of *Chrysophyllum albidum* contain approximately 16.6% lipids, with unsaturated fatty acids comprising 74% of the extracted oil [5]. Ajewole and Adeyeye further confirmed that unsaturated fatty acids constitute the major component of the oil (74%), which is desirable for reducing the risk of heart disease [6]. Additionally, the methanol extract of both the seed and root of *Chrysophyllum albidum* has exhibited antihistamine and anti-inflammatory activities [7], while the fruit's exocarp extract has demonstrated free radical scavenging activity [8].

This research project aims to extract oil from the seeds of *Chrysophyllum albidum*, commonly known as Africa Star Apple, and evaluate its oil yield and physicochemical properties. The primary objective is to assess the industrial and economic potential of *Chrysophyllum albidum* as an oilseed crop by thoroughly analysing these factors. Additionally, an in-depth study of the physicochemical properties will provide valuable insights into the suitability of the extracted oil for diverse applications in the food, cosmetic, and related industries

2. Material and Methods

2.1. Fruit collection and Seeds preparation

Fresh ripe fruits of *Chrysophyllum albidum* were purchased from local markets in the Ashanti Region, Eastern Region, and Greater Accra Region. The seeds were extracted from the fruits, decorticated, and the resulting cotyledons were dried under ambient conditions for one week. Oven drying was avoided to prevent the loss of constituents due to thermal degradation. The dried cotyledons were then ground into smaller particles (powder) using a porcelain mortar and pestle.

2.2. Oil extraction and concentration procedure

2.2.1. Soxhlet extraction

A weight of 180 grams of the powdered sample was filled into a thimble. The round bottom flask of the Soxhlet extractor was filled with 250 ml of the solvent (normal hexane). The reflux condenser was fitted to the top of the extractor, and the water flow was turned on. The round bottom flask was placed in a water bath, and the temperature of the water bath was adjusted to 65 °C, as the boiling point of normal hexane ranges from 55 to 65 °C, bringing the solvent to its vaporisation point. Each extraction process took place over a period of 6 to 8 hours. The extract was then poured into a conical flask and exposed to air for the solvent to evaporate.

2.2.2. Maceration

The powdered sample was soaked in 250 ml of normal hexane for 72 hours. The glass container used for soaking was tightly covered, and the mixture was periodically shaken throughout the 72 hours. Afterward, the sample was filtered, and the filtrate was exposed to air for the normal hexane to evaporate, leaving behind the oil.

2.3. Determination of physicochemical properties of the oil

2.3.1. Percentage oil yield

The formula that was used for calculating percentage oil yield is

$$\%\ yield = \frac{mass\ of\ oil}{mass\ of\ sample\ used}\ x\ 100$$

2.3.2. Colour and odour

The colour of the oil refers to its appearance compared to standard rainbow colours, while the odour refers to the smell. These properties were determined through direct physical observation of the oil and compared with existing oils.

2.3.3. Determination of refractive index (RI)

The refractive index of the oil was determined using an Abbe refractometer.

The prism case of the instrument was opened, cleaned, and enough oil was pipetted to cover the entire surface of the prism. Visual observation was made through the instrument's eyepiece, and the prism adjustment knob was turned until a distinct light or dark border became visible. The compensator dial was adjusted to remove as much colour as possible from both the light and dark areas.

The eyepiece was also adjusted to bring the light and dark border into sharp focus while readjusting the prism knob to place this border in the centre of the crosshairs. From the instrument scale, the Brix and the temperature of the oil were read. The Brix value was then converted to a refractive index using the International Commission for Sugar Analysis scale, which contains Brix values and their corresponding refractive indices [9].

2.3.4. Determination of specific gravity (SG)

A 2 ml pipette was used to measure 2 ml of oil, and the mass of the oil was weighed using an electronic balance (Sartorius). The mass of the oil was found to be 1.99 g. The mass of an equal volume of distilled water was also determined using the same method and was measured to be 2.12 g. The specific gravity of the oil was then calculated using the formula:

$$\text{Specific gravity} = \frac{mass\ of\ oil}{mass\ of\ equal\ volume\ of\ water}$$

2.3.5. Determination of iodine value

0.5 g of the oil was weighed into a 250 ml conical flask, and 20 ml of carbon tetrachloride solution was added. 25 ml of Hanus solution was added to the flask, and the flask was covered with a piece of aluminium foil. The solution was shaken for one minute and kept in a dark place for thirty minutes. 10 ml of 0.1 N potassium iodide (KI) was added, followed by 100 ml of distilled water. The solution was shaken for 30 seconds, and 10 ml of starch indicator was added. 0.1 N sodium thiosulphate ($Na_2S_2O_3$) solution was then titrated against the solution in the flask, and the volume was recorded. This process was repeated three times. The same procedure was carried out for the blank.

The iodine value was then calculated using the formula:

$$IV = \frac{12.69(Vc - Vs)}{W}$$

Vc = volume of $Na_2S_2O_3$

Vs = volume of $Na_2S_2O_3$ used for the sample titration

W = weight of sample

N = normality of $Na_2S_2O_3$

2.3.6. Determination of peroxide value

2.0 g of oil was weighed into a conical flask, and 12 ml of chloroform, 10 ml of acetic acid, and 0.5 ml of 0.1 N potassium iodide (KI) were added. Then, 30 ml of distilled water was added. Quickly, 0.5 ml of starch indicator was added to make the yellow colour disappear and a faint blue colour appeared. 0.1 N sodium thiosulphate ($Na_2S_2O_3$) solution was titrated against the content in the conical flask until the faint blue colour disappeared. This procedure was repeated three times. A blank was also prepared using the same method and titrated with 0.1 M $Na_2S_2O_3$.

The peroxide value was then calculated using the formula,

$$PV = \frac{100N\ (Vs-Vc)}{W}$$

Vs = volume of sodium thiosulphate used in the sample titration

Vc = volume of sodium thiosulphate in the control titration

W = weight of oil sample

N = normality of sodium thiosulphate

2.3.7. Determination of acid value and free fatty acid

2.0 g of oil was weighed into a conical flask, and 20 ml of ethanol was added, followed by three drops of phenolphthalein. The mixture was titrated with 0.1 N aqueous potassium hydroxide (KOH) solution until a persistent faint pink colour appeared for 10 seconds. This process was repeated three times. The same procedure was carried out for the blank. The acid value was calculated using the formula:

$$AV = \frac{56.1\ NV}{W}$$

V = volume in ml of KOH

N = normality of KOH solution

W = weight in grams of sample

$$\text{Free fatty acid} = \frac{Acid\ value}{1.99}$$

2.3.8. Determination of saponification value

0.1 g of oil was weighed into a conical flask, and 25 ml of the alcoholic KOH (1:1) solution was added. The contents were stirred for 5 minutes and then boiled for one hour using a condenser. The resulting solution was titrated against 0.1 M aqueous HCl using phenolphthalein as an indicator. The experiment was repeated three times. The same procedure was followed for the blank.

The saponification value was calculated using the formula.

$$SV = \frac{56.1\ N\ \ (Vc-Vs)}{W}$$

Vc = volume of standard HCl in the control

Vs = volume of HCl in the sample test

W = weight of oil taken for the test

N = normality of standard HCl solution

3. Results and discussion

Two methods of extraction were used to determine which would yield a higher percentage of oil. The methods used were Soxhlet extraction and maceration, both utilising normal hexane as the solvent, as presented in Table 1.

The physical properties of the extracted oil were determined using the standard protocol prescribed by AOAC [10]. All the parameters were compared with the available standards, and the results are presented in Table 2.

Table 1 Percentage of oil yield using the two extraction methods

Method of extraction	Mass of sample (g)	Mass of oil (g)	Percentage oil yield (%)
Soxhlet extraction	120	2.562	2.135
Maceration	180	1.99	1.24

Table 2 Comparison of obtained physical properties with available standards

Parameters	Results obtained	WHO/ FAO Edible oil standards [11]	India medicinal oil standards [12]
Specific gravity	0.94	-	-
Refractive index	1.3648 at 20 °C	1.449- 1.476	-
Colour	Deep yellow	-	-
Odour	Not offensive	-	-

Chemical properties of the extracted oil were determined using the standard protocol prescribed by AOAC [10]. All the parameters were compared with the available standards, and the results are presented in Table 3.

Table 3 Comparison of obtained chemical properties with available standards

Parameter	Results obtained	WHO/FAO Edible oil standards [11]	India Medicinal oil Standards [12]
Acid value (meq/kg)	5.52	$\leq$ 0.6	0.548 - 0.972
Free fatty acid (%)	2.76	0.085 -1.376	-
Peroxide value (meq KOH/g)	4.52	$\leq$ 10	2.68 - 3.59
Iodine value (mg/g oil)	126. 6804	50 -143	-
Saponification value (mg KOH/g)	181.203	187 - 209	123 - 196

3.1. Physical properties

The oil yield obtained from the Soxhlet extraction method was 2.135%, while the yield from maceration was 1.24%. These values were significantly lower compared to the reported values for other seeds, such as neem seeds (46%), cotton seeds (24%), and groundnut (46%) [13]. Additionally, the oil quantity obtained from *Chrysophyllum albidum* seeds, as reported by other researchers in Nigeria [2,3,5], was also higher than the yields obtained in this study. These findings suggest that *Chrysophyllum albidum* seeds may not be a rich source of abundant oil. However, genetically modified breeds may be developed that could produce seeds with a higher oil yield. In this study, Soxhlet extraction, which yielded 2.135% of oil, proved to be a more effective extraction method for samples with very low oil content, such as *Chrysophyllum albidum*, compared to maceration, which yielded 1.24% of oil.

The extracted oil exhibited a deep yellow colour and had a pleasant, sweet smell without any offensive odour. Colour is a crucial parameter that influences consumer acceptability of oil products, and commercial oils typically have a yellow hue. The colour of the tested seed oil was assessed through direct visual observation. The development of colour in seed oil is primarily attributed to the presence of pigments such as chlorophyll and carotenoids [3], which are unintentionally extracted during the oil extraction process. Removing such colouring plant pigments is important from a commercial standpoint. The process of bleaching is employed during oil and fat processing to reduce and eliminate the colour [14].

The specific gravity of the oil at 20 °C was measured to be 0.94, which displayed a significant difference compared to the specific gravity values of sunflower seed oil (0.877), cotton seed oil (0.874), corn oil (0.868), and palm oil (0.880)

[15]. However, the specific gravity value of the oil was relatively similar to that of certain cucurbits such as white melon, gourd, pumpkin, and watermelon seed oil, which ranged from 0.896 to 0.93 [16-19]. The specific gravity value of 0.94 indicates that the oil is less dense than water, which aligns with the findings of Belewu *et al*. [20] and Tint and Mya [21] regarding *Jatropha curcas* seed oil. According to Galley [15], seed oils with specific gravity values within the range of 0.8800-0.9400 are suitable for edible purposes, while those with values ranging from 0.8114 to 1.0714 have more potential for biofuels. Therefore, the specific gravity of the tested o il falls within the edible range.

The refractive index of the oil at 20 °C was found to be 1.364, which differs noticeably from the value of 1.46 found for African star apple seed oils by Ochigbo and Paiko [1]. This suggests that the oil being tested is less thick or viscous compared to the majority of drying oils, which typically have refractive indices between 1.475 and 1.485 [22]. Additionally, the 1.364 did not meet the WHO/FAO requirements for edible oils [11], which range from 1.449 to 1.476. However, this value aligns with the findings of Audu *et al.* [5] and falls within the range of results for soybean and maize oils reported in other studies [23].

Physical characteristics such as the refractive index and specific gravity provide valuable insights into the purity of vegetable oils. Deviations from the specified requirements raise concerns about possible adulteration of the oil. Each oil type has defined ranges for these parameters. As noted by Gull *et al.* [24], both characteristics contribute to assessing the relative purity and identity of oils and fats.

3.2. Chemical properties

Peroxide value is an index of rancidity, indicating the oil's resistance to peroxidation during storage [25]. The peroxide value of *Chrysophyllum albidum* seed oil in this study was 4.50 meq/KOH/g, which is below the WHO/FAO standard value of 10 meq/KOH/g [11] and the maximum acceptable value set by the Codex Alimentarius Commission for oils like groundnut seed oil [26]. However, it varies considerably from the India Medicinal oils standards [12] suggesting that *Chrysophyllum albidum* seed oil may not be suitable for medicinal purposes based on its peroxide value. A low peroxide value indicates oil stability, and fresh oils typically have values below 10 meq/kg. Higher values between 20 and 40 result in a rancid taste [27]. The low acid and peroxide values indicate the oil's ability to resist lipolytic hydrolysis and oxidative deterioration [28].

The acid value is a direct measure of the percentage content of free fatty acids in a given amount of oil. It reflects the extent to which the triglycerides in the oil have been decomposed into free fatty acids through either chemical or lipolytic hydrolysis. Chemical hydrolysis is primarily caused by moisture, while lipolytic hydrolysis is due to the presence of natural enzymes, especially lipases. A higher magnitude of free fatty acids indicates a higher degree of hydrolysis and poorer oil quality. Acid value is also used as an index of freshness [1]. In this study, the acid value and free fatty acid value obtained were 5.52 and 2.76 mg/KOH/g, respectively. These values differ significantly from the WHO/FAO standards for edible oil [11] and the India Medicinal oil standards [12] but align with those reported by Eka and Chidi [29] for butternut oil and Akubugwo and Ugbogu [27] for African star apple oil. The obtained values also agree with Pearson [30], who reported acid values of 4 for sesame, soybean, sunflower, and rapeseed oils, and 7 for olive oil. Therefore, the low magnitude of the acid and free fatty acid values indicates the freshness and edibility of the crude oil.

The iodine value measures the unsaturation of fats and oils, with a higher value indicating higher unsaturation. Oils with values below 112 g/100g oil may find use in the confectionery and biofuels industries. Oils with high unsaturation of fatty acids are prone to polymerization of the glycerides when heated, leading to the formation of deposits and compromising oxidative stability. With an iodine value of 126.68 g/100g, the oil from *Chrysophyllum albidum* seed can be considered a drying oil. However, it may not be suitable for use in the paint industry in its crude form due to its potential for polymerization. The iodine value aligns with the WHO/FAO standards for edible oil [11], indicating that the oil could be considered edible based on its iodine value.

The saponification value is used to detect adulteration and is inversely proportional to the molecular weight of the oil; higher values indicate lower molecular weight [5]. In this study, the saponification value of *Chrysophyllum albidum* seed oil was 181.203 meq/KOH/g, which is more than twice the value reported for *Luffa cylindrica* oil (65.92 mg KOH/g) [31], but aligns with that reported by Adebayo *et al.* [2]. The saponification value slightly deviates from the WHO standards for edible oil [11] but agrees with the India Medicinal oil standards [12], suggesting that it can be considered edible based on its saponification value.

4. Conclusion

The analysis of the physicochemical properties of the extracted seed oil of *Chrysophyllum albidum* grown in Ghana indicates that some of the oil's properties meet the standards for edible oils, although it is not refined. The results demonstrate that the oil possesses good resistance to rancidity during storage and has a high level of unsaturation. Refining the oil could further enhance its properties for both domestic and industrial applications. However, it should be noted that the seed of *Chrysophyllum albidum* may be considered a low oil-yielding seed based on the percentage oil yield obtained in this study. It is worth noting that there are different species of *Chrysophyllum albidu*m, and comparing the oil yield in this study with those from other studies conducted in Nigeria reveals variations

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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