



Comparative Assay of the Nutritional Composition and Antioxidant Effect of the Cotyledon and Pulp of *Chrysophyllum albidum* fruit

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Authors' contributions

This work was carried out in collaboration among all authors. Author IOI designed and supervised the study. Author PUE managed and performed the experimental and statistical aspects of the study. Author UCO wrote the protocol and first draft of the manuscript while author JN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: *Chrysophyllum albidum* has been widely consumed for its flesh part as a fruit snack and source of vitamins but also grossly under-utilized because of dearth of knowledge on nutritional and therapeutic potencies of other fruit parts. This study thus aimed to comparatively determine the nutritional, phytochemical and *in vitro* antioxidant properties of the flesh and cotyledon of *C. albidum*.

Methods: Proximate and phytochemical contents were determined according to the methods of Association of Official Analytical Chemists (2000). Mineral concentrations were evaluated using Atom Analyzer according to the protocols of AOAC (2000). Antioxidant properties were assayed through the 2,2-diphenyl-1-picryl hydrazyl radical scavenging, reducing power and lipid peroxidation abilities according to the methods of Barros *et al* (2007).

Results: Findings indicated a higher percentage contents of ash (3.83 ± 0.38), moisture (13.86 ± 0.84), crude fiber (11.07 ± 2.72) and crude protein (7.44 ± 0.44) in the flesh than the cotyledon of *C.*

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albidum, which were insignificantly different ($p > 0.05$). On the other hand, crude fat (13.80 ± 2.60) and total carbohydrate (64.96 ± 2.77) were found to be more in the cotyledon than the flesh but also not significantly different ($p > 0.05$). The mineral analysis revealed a higher but insignificantly different ($p > 0.05$) concentrations of iron (2.31 ± 0.22), copper (1.23 ± 0.09), zinc (2.94 ± 0.12) and potassium (1.48 ± 0.09) in the flesh than the cotyledon whereas cobalt (3.09 ± 0.92), magnesium (21.13 ± 0.58), sodium (16.27 ± 0.62) and selenium (4.24 ± 0.28) were more in the cotyledon than the flesh although insignificantly different ($p > 0.05$). While the flesh was observed to significantly contain high total phenol values, the cotyledon showed more significant mean values for tannin, oxalate, saponin and β -carotene than the flesh. The *in vitro* DPPH free radical scavenging and lipid peroxidation inhibition findings indicated higher antioxidant activities in the flesh than in the seed.

Conclusion: Conclusively, the flesh and seed fruit parts of *C. albidum* showed considerable and significant amounts of the parameters under study, which can be further exploited for their nutritional and pharmacological essence.

Keywords: *Chrysophyllum albidum*; pulp; cotyledon; proximate; phytochemical; antioxidant.

1. INTRODUCTION

Fruits are important for a balanced diet, mostly because they are good sources of nutritional components especially vitamins and minerals required for diverse physiologic and metabolic processes. Plants and fruits have been employed in the treatment and management of diseases. This can be attributed to the presence of bioactive constituents with pharmacologic efficacies. Consumption of fruits and herbs have thus been linked to low incidences of risks of many ailments [1].

Recently, focused attention is increasing towards the use of natural antioxidants to forestall the pathogenesis of oxidative stress related ailments. Polyphenolic compounds are gaining much of this attention. This is because of the acknowledgement of their antioxidant properties, great abundance in our diet, and possible role in the prevention of some diseases associated with oxidative stress, such as cancer, certain circulatory and neurodegenerative diseases [2]. Polyphenols are active substances found in medicinal plants. They modulate the activity of a wide range of enzymes and cell receptors. The protective effect of fruits in impeding or delaying oxidative stress in ageing and the reduced risk of chronic diseases have been attributed to the antioxidant potentials of their polyphenol contents [3].

Chrysophyllum albidum is a medium sized, evergreen tree usually 70 to 100 feet high [4]. The tropical tree belongs to the family *Sapotaceae* and is commonly known as African Star Apple. It is widely distributed in Nigeria, Uganda, Niger, Cameroun and Cote d' Ivoire [5,6]. It is greenish in colour when unripe and turns pale orange when ripe. The fruit, pointed at

both ends, are about 4 cm wide and shaped like orange or apple but smaller. It is often cultivated for its edible fruits and the pulp has a pleasant acid taste. The seed coats are hard, bony, shiny, and dark brown, and when broken reveal white-colored cotyledons [7]. In Nigeria, *C. albidum* is known as "Agbalumo" in Southwestern Nigeria and "Udara" in Southeastern Nigeria. The fruit pulp is usually the most consumed edible part of the fruit. Although, the cotyledons encapsulated within the seed shell are also edible, they are most times discarded because they are enclosed within a hard shell that is inedible [4]. The roots, barks, fruit pulp and seeds of *Chrysophyllum albidum* have different medicinal uses. For instance, Anang et al. [8] reported that the roots, bark and the leaf of *C. albidum* are used as natural remedy for sprains, bruises and wounds in Southern Nigeria and also inhibit microbial growth of known wound contaminants. The high saponin content of *C. albidum* leaves and roots justifies the use of the extracts to control human cardiovascular disease and reduce blood cholesterol as documented by Aletor [9].

Upon the foregoing backdrop, the present study thus aimed to comparatively investigate the nutritional composition and antioxidant effect of the cotyledon and pulp of *C. albidum* fruit with a view to possibly expanding utilization options for treatment and nutrition.

2. MATERIALS AND METHODS

2.1 Study Site

This research was carried out at Natural Products Research and Development Laboratory, Special Research Centre, Nnamdi Azikiwe University, Awka.

2.2 Collection and Identification of Sample

Fresh ripe *C. albidum* fruits were purchased from Nkwo market in Igbo-Ukwu, Aguata Local Government Area, Anambra State, Nigeria. The plant sample was identified and authenticated by a taxonomist at the Department of Botany, Nnamdi Azikiwe University, Awka.

2.3 Preparation of Sample

The ripe, freshly collected *C. albidum* fruits were carefully washed and separated into back peels, fruit pulp, and seed. Afterwards, the hard shells of the seeds were broken to reveal the cotyledon. Both the fruit pulp and cotyledon were sun-dried for 7 days and milled into powder using hand mill. The powdered samples were stored in airtight container until further analysis. Each powdered sample were extracted in hydroethanol by soaking 1 kg of each part separately in 1 litre of 70 % ethanol. They were allowed to stand for 48 hours at room temperature with intermittent shaking and later filtered using three layers of muslin cloth followed by Whatman No 4-filter paper. The filtrates were further concentrated by evaporation to dryness. An aliquot of the slurry remaining after evaporation was redissolved in distilled water at a concentration of 10 mg/ml and stored in a refrigerator as stock for the *in vitro* antioxidant assays [10]. The remaining portion were used for phytochemical analysis.

2.4 Proximate Analysis

The moisture, ash, crude fiber and crude fat were determined using standard methods according of the Association of Official Analytical Chemists [11]. Crude protein was determined by the Micro-Kjeldahl method as proposed by AOAC [11]. The total percent carbohydrate content was estimated by the difference of 100 of the other proximate components as reported by Yerima and Adam [12] using the following formular:

$$\text{Total Carbohydrate (\%)} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Crude fibre} + \% \text{ Crude protein} + \% \text{ Fat})$$

2.5 Mineral Analysis

Determination of concentrations of iron, manganese, copper, cobalt, zinc, magnesium, sodium, potassium, selenium and calcium were carried out using Atom Analyzer method in an Atomic Absorption Spectrophotometer 969 instrument [13].

2.6 Phytochemical Analysis

Quantitative phytochemical contents were carried out as reported below: Total phenols and flavonoids were determined by modified colorimetric tests as described by Barros *et al* [10]. Cardiac glycosides and oxalate were estimated according to the method of Osagie [16]. Phytate content was determined using the method of Young and Greaves [14]. The saponin content of the extract solution was determined by the method of Obadoni and Ochuko [15]. The alkaloid content was determined by the method of Harborne [17]. Tannin content was determined according to method of AOAC [18] while lycopene and β -carotene were determined by a different method of estimation described by Barros *et al* [10].

2.7 *In vitro* Antioxidant Assays

2.7.1 DPPH free radical scavenging activity

The stable 2, 2-diphenyl-1-picryl hydrazyl radical (DPPH) was used for the determination of free radical scavenging activity of the methanol extract of the samples. This was assayed using the method of Ebrahimzadem *et al.* [19]. Different concentrations of the extract (0-1000 μ g/ml) were mixed with an equal volume of methanolic solution of DPPH (100 μ M) in a test tube. The mixture was shaken and kept in the dark for 30 minutes. The absorbance was read at a wavelength of 517 nm using spectrophotometer. Butylated hydroanisole (BHA) was used as standard. The percentage scavenging activity was calculated using the formula:

$$\% \text{RSA} = [(A_{\text{DPPH}} - A_s) / A_{\text{DPPH}}] \times 100$$

Where A_s is the absorbance of the test solution with the sample and A_{DPPH} is the absorbance of DPPH solution. The EC_{50} (concentration of sample at 50% RSA) was calculated from the graph of %RSA against the sample concentration.

2.7.2 Reducing power assay

The reducing power was determined according to the method of Barros *et al.* [10]. This method is based on the principle of increase in the absorbance of the reaction mixture. Various concentrations of methanol extract of the samples (0-1000 μ g/ml) were mixed with 2.5 ml of 0.2 M sodium phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide. The mixture

was incubated at 50°C for 20 minutes. Exactly 2.5 ml of 10% trichloroacetic acid was added and the mixture centrifuged at 1000 rpm for 8 minutes. The upper layer (5 ml) was mixed with 5 ml of deionized water followed by the addition of 1 ml of 0.1 % ferric chloride. The absorbance was measured at 700 nm. The graph of absorbance at 700 nm against the extract concentrations was plotted. BHA was used as the standard according to the method of Barros *et al.* [10]

2.7.3 Assay of inhibition of lipid peroxidation using tba reactive substance

This was determined by the method of Barros *et al.* [10]. Determination of the extent of inhibition of lipid peroxidation was carried out using homogenate of the brain of a goat. The brain was gotten from a goat of approximately 60 kg body weight purchased from Kwata Slaughter at Awka. The brain was dissected and homogenized with pestle and mortar in an ice-cold Tris-HCl buffer (pH 7.4, 20 mM) to produce 10% w/v brain homogenate which was centrifuged at 3000 rpm for 10 min. An aliquot (0.1 ml) of the supernatant was incubated with 0.2 ml of the sample extract at various concentrations (0-1000 µg/ml), in the presence of 0.1 ml of 10µM ferrosulphate and 0.1 ml of 0.1 mM ascorbic acid at 37°C for 1 hour. The reaction was stopped by the addition of 0.5 ml of 28 % TCA (Trichloro acetic acid) followed by the addition of 0.38 ml of 2% TBA (Thiobarbituric acid). The mixture was then heated at 80°C for 20 minutes. After centrifugation at 3000 rpm for 10 minutes to remove the protein, the colour intensity of the malondialdehyde (MDA)-TBA complex in the supernatant was measured by its absorbance at 532 nm. The inhibition ratio (%) was calculated using the following formula:

$$\text{Inhibition ratio (\%)} = [(A-B)/A] \times 100\%$$

Where A and B are the absorbance of the control and the compound solution respectively. The extract concentration providing 50% lipid peroxidation inhibition (EC₅₀) was calculated from the graph of antioxidant activity percentage against the extract concentrations. BHA was used as the standard.

2.8 Data Analysis

Data was analyzed using SPSS statistical software package (SPSS for Windows, version 21, IBM Corporation, NY, USA). One-way Analysis of Variance was used to test for variability between the mean values while Tukey's HSD *post-hoc* test was employed for multiple comparisons. Data was presented as the mean ± Standard deviation of triplicate determinations. Values were considered significantly different at $p < 0.05$.

3. RESULTS

3.1 Proximate Analysis of Flesh and Cotyledon of *C. albidum*

The proximate analysis of the fruit and cotyledon of *C. albidum* is presented in Table 1. The findings are expressed as Mean ± Standard deviation of triplicate determinations. The percentage of ash, moisture, crude fiber and crude protein were all found to be higher in the flesh than the cotyledon with mean values of 3.83 ± 0.38 , 13.86 ± 0.84 , 11.07 ± 2.72 and 7.44 ± 0.44 , respectively. However, they were observed to be statistically not significant different ($p > 0.05$). On the other hand, the proximate analysis observed a higher mean values of percentage crude fat and carbohydrate contents for the cotyledon than for the flesh of *C. albidum*. These values were also not statistically significantly different ($p > 0.05$).

Table 1. Proximate analysis of the flesh and cotyledon of *C. albidum*

Proximate parameters (%)	Flesh	Cotyledon
Ash	3.83 ± 0.38	2.36 ± 0.08
Moisture	13.86 ± 0.84	11.51 ± 0.44
Crude fiber	11.07 ± 2.72	1.45 ± 0.05
Fat	7.60 ± 0.60	13.80 ± 2.60
Crude protein	7.44 ± 0.44	5.90 ± 0.65
Total carbohydrate	56.18 ± 1.33	64.96 ± 2.77

Results are expressed as Mean ± Standard deviation of triplicate determinations

3.2 Mineral Analysis of Flesh and Cotyledon of *C. albidum*

The flesh and cotyledon of *C. albidum* showed remarkable presence of some essential macronutrients as presented in Table 2. The analysis observed a significant concentration (ppm) of Na, Mg, Se and Co in the cotyledon of *C. albidum* than in the flesh. On the other hand, Fe, Mn, Cu, Zn and K had considerable amounts in the flesh than in the cotyledon. However, the mean values of the observed metals in both samples were found to be not statistically significantly different ($p > 0.05$) at 95% confidence interval.

3.3 Phytochemistry of Flesh and Cotyledon of *C. albidum*

The phytochemical analysis of the flesh and cotyledon of *C. albidum* plant is presented in Table 3 below. Generally, from the investigations, both flesh and cotyledon of *C. albidum* expressed considerable amounts and presence of phytochemicals, which indicate the numerous potential anti-microbial, pharmacological, and therapeutic activities attributable to any plant sample. For the phytochemicals determined quantitatively, the results showed higher values of the following phytochemicals in the cotyledon: tannin (94.84 ± 1.80), oxalate (8.91 ± 0.27), saponins (4.20 ± 0.00), β -carotene (0.35 ± 0.00). The mean values of these phytochemicals, however, were found to be statistically significantly different ($p < 0.05$). Similarly, total alkaloids (4.32 ± 0.36), phytate (0.32 ± 0.04), cardiac glycosides (3.25 ± 0.25) and lycopene (0.14 ± 0.00) were observed to be higher in the cotyledon than in the flesh but, nonetheless, not statistically significantly different ($p > 0.05$). Percentage flavonoids compared

fairly equally in both flesh and cotyledon. Only total phenol was found to be higher in the flesh (86.05 ± 0.73) than in the cotyledon (63.31 ± 1.98) and a statistically significant difference ($p < 0.05$) observed between the two mean values.

3.4 *In vitro* Antioxidant Activity of Flesh and Cotyledon of *C. albidum*

3.4.1 DPPH free radical scavenging activity of *C. albidum*

The *in vitro* antioxidant activities of the flesh and cotyledon of *C. albidum* are shown in Figs. 1, 2 and 3 below. Fig. 1 shows the DPPH free radical scavenging activities of the flesh and cotyledon of *C. albidum*. The Fig. reveals the flesh of *C. albidum* exhibited 88.56% ability at scavenging free radicals produced by DPPH than the cotyledon (62.55%) and synthetic antioxidant butylated hydroxyanisole (BHA) [69.97%] at a concentration of 1000 $\mu\text{g/ml}$ though both parts of the plant were better at resolving free radicals than BHA. Also, at increasing concentrations, the activity of the investigated plant parts increased significantly.

3.4.2 Reducing power activity of *C. albidum*

The figure below shows the *in vitro* reducing power of both the flesh and cotyledon of *C. albidum* in comparison to the standard synthetic antioxidant, butylated hydroxyanisole. The Fig. shows both the flesh and cotyledon of *C. albidum* to have higher activity at reducing free radicals at lower concentrations than BHA. Also, at higher concentration (1000 $\mu\text{g/ml}$), the cotyledon showed a better activity at reducing free radicals *in vitro* than the flesh of *C. albidum* and BHA.

Table 2. Mineral analysis of flesh and cotyledon of *C. albidum*

Mineral (ppm)	Flesh	Cotyledon
Iron	2.31 ± 0.22	1.70 ± 0.53
Manganese	0.54 ± 0.07	0.51 ± 0.05
Copper	1.23 ± 0.09	0.79 ± 0.06
Cobalt	2.40 ± 0.53	3.09 ± 0.92
Zinc	2.94 ± 0.12	0.13 ± 0.02
Magnesium	5.53 ± 0.71	21.13 ± 0.58
Sodium	13.07 ± 0.53	16.27 ± 0.62
Potassium	1.48 ± 0.09	0.84 ± 0.09
Selenium	3.96 ± 0.08	4.24 ± 0.28
Calcium	5.99 ± 0.21	5.98 ± 0.40

Results are expressed as Mean \pm Standard deviation of triplicate determinations

Table 3. Phytochemical analysis of flesh and cotyledon of *C. albidum*

Phytochemicals	Flesh	Cotyledon
Total alkaloids (%)	4.22 ± 0.02	4.32 ± 0.36
Total flavonoids (mgCE/g)	0.29 ± 0.11	0.28 ± 0.00
Tannins (mgTAE/g)	38.14 ± 2.18	94.84 ± 1.80
Total phenol (mgGAE/g)	86.05 ± 0.73	63.31 ± 1.98
Oxalate (mg/g)	3.24 ± 0.27	8.91 ± 0.27
Saponin (%)	0.07 ± 0.01	4.20 ± 0.00
Phytate (%)	0.25 ± 0.06	0.32 ± 0.04
Cardiac glycosides (%)	2.00 ± 0.50	3.25 ± 0.25
Beta carotene (mg/g)	0.29 ± 0.00	0.35 ± 0.00
Lycopene (mg/g)	0.11 ± 0.01	0.14 ± 0.00

Results are expressed as Mean ± Standard deviation of triplicate determinations

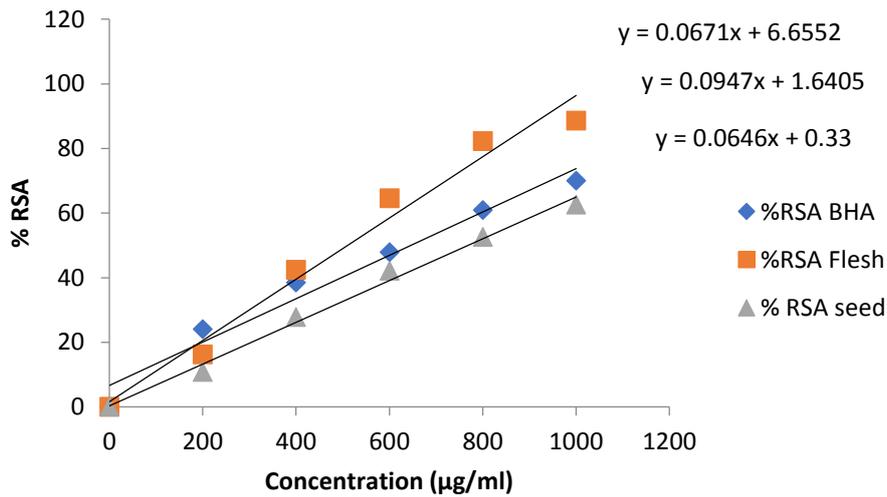


Fig. 1. The DPPH free radical scavenging activities of the flesh and cotyledon of *C. albidum*

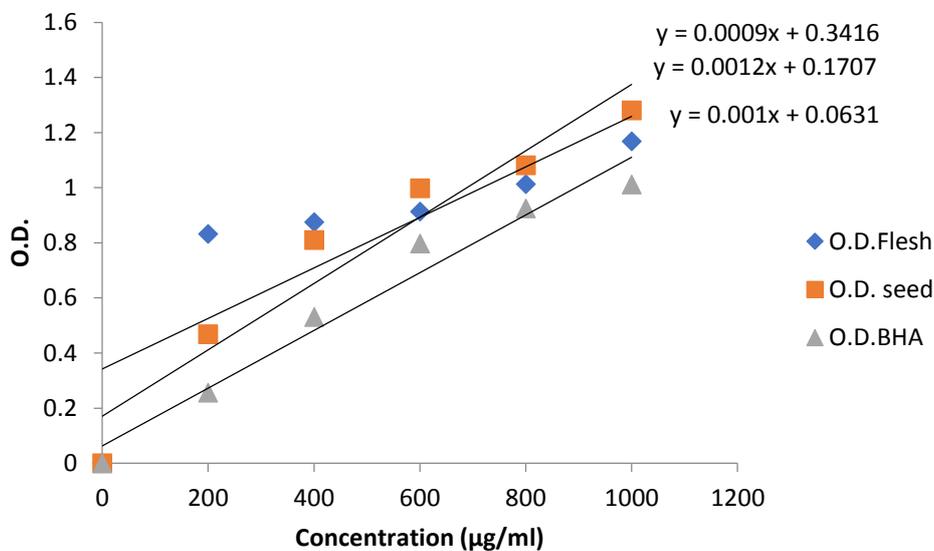


Fig. 2. The reducing power activities of the flesh and cotyledon of *C. albidum*

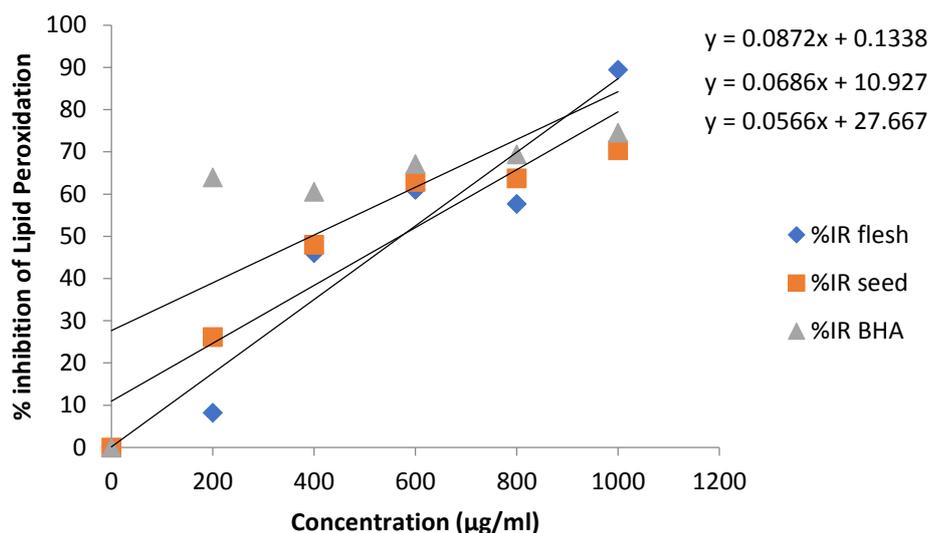


Fig. 3. The % lipid peroxidation inhibition activities of the flesh and cotyledon of *C. albidum*

3.4.3 Lipid peroxidation inhibition of *C. albidum*

The percentage of inhibition of lipid peroxidation in the flesh and cotyledon of *C. albidum* are shown in the figure below. At a concentration of 1000 µg/ml, the flesh expressed the highest lipid peroxidation inhibitory activity of 89.51% than the cotyledon (70.45%) and standard synthetic antioxidant, butylated hydroxyanisole (74.61%) though at lower concentrations, BHA showed the highest inhibitory activity in contrast to the flesh and cotyledon of *C. albidum*. On the other hand, the cotyledon showed better inhibitory activity than the flesh at lower concentrations indicating that the flesh can only inhibit lipid peroxidative activity at higher concentrations of intake.

4. DISCUSSION

Fruits have been known to be good sources of vitamins and nutritional components for a healthy well-being and efficient metabolic biochemical processes [2]. In addition to providing nutrients, they are eaten for aesthetics. Beyond this, consumption of fruits and vegetables has been linked to lowered incidences of risk for coronary heart diseases, obesity, cancer, hypertension, and diabetes [21-23]. *Chrysophyllum albidum* among other fruits of tropical origin have been adjudged beneficial for their nutritional and therapeutic values and hence drawn attention of various researchers to explore and exploit its potentials in phytomedicine [24]. This study thus aimed to investigate and compare the proximate,

mineral, phytochemical and *in vitro* antioxidant activity of the flesh part and cotyledon of *C. albidum* fruit plant.

The proximate analysis of edible fruits and vegetables helps in assessing their nutritional significance and findings of the work revealed that the proximate ash content of the flesh was higher than that of the cotyledon. This value was higher than those reported for the flesh in a study by Amusa *et al* [7] and Musa *et al* [25] but are in close range with that obtained by Ibrahim *et al* [21] and Ukana *et al* [26]. The ash content obtained for the cotyledon in this study compared with that of Ukana *et al* [26] but higher than that observed in Egbuonu *et al* [27]. In the present study, the ash content of the edible flesh was found to be higher than the cotyledon indicating the presence of more inorganic constituents in the flesh than in the cotyledon. This means that the edible flesh can provide inorganic food components as well as the cotyledon part. The ash content is indicative of the amount of inorganic matter and oxides present in any food sample [28].

The moisture content of any food material is a measure of the perishability and life span of the food and indicates how long it can stay without growing molds [29]. In the present study, a moisture content of 13.86 ± 0.84 was observed for the flesh higher than the value for 11.51 ± 0.44 in the cotyledon. This finding for the flesh, was however higher than those of Ibrahim *et al* [21] but lower than that obtained by Asare *et al*

[30] and Ibrahim *et al* [31]. The low moisture content implied a dry flesh with longer preservation period.

The crude fibre in the study was found to be higher in the flesh than in the cotyledon. The value was found to be higher than that obtained by Ibrahim *et al* [31] but lower than that of Ibrahim *et al* [21]. The cotyledon crude fiber as obtained by Ibrahim *et al* [21] was also found to be higher than that of the present work but then corresponds comparatively with that observed for the cotyledon by Egbunu *et al* [27]. Consumption of fiber is biochemically important as it may contribute to the reduction in the incidence of certain diseases like colon cancer and other digestive disorders [32], increases fecal bulk and rate of intestinal transit and may result in prebiotic effects [32]. Thus, the presence of crude fiber in both flesh and cotyledon of *C. albidum* can aid in mitigating against these digestive disorders.

Crude fat of the flesh and cotyledon of *C. albidum* in this study were reported to be higher in the cotyledon than the flesh. These findings agree comparatively with the values earlier reported by Ibrahim *et al* [29] for the pulp but was found to be higher than that obtained for the flesh by Ibrahim *et al* [21] and Musa *et al* [25] for the pulp. The significance of estimating the crude fat or lipid content of *C. albidum* lies with the fact that lipids are known to be important components of cell membranes, facilitate transport of fat-soluble vitamins, are physiological precursors to biological hormones biosynthesis, insulate and protect internal tissues and ultimately provide adequate energy for metabolic processes [22]. However, high consumption of fats has been linked to prevalent incidences of heart-related diseases. With considerable amounts of fats present in both flesh and cotyledon of *C. albidum*, it remains characterization of the extracted oil in order to exploit it for domestic, industrial and commercial applications and possible potential health benefits. Proteins are excellent sources of both essential and non-essential amino acids required for growth, development and repair of worn-out tissues. In the present study, crude protein content was expressed as a percentage of the organic nitrogen content and based on this, findings showed a higher value of protein in the flesh than in the cotyledon. These findings were closely within range and consistent with the earlier works of Ibrahim *et al* [21] and Amusa *et al* [7] but lower in value than that reported by Musa *et al* [25] and

Egbunu *et al* [27]. Estimating protein contents provide and indicate the nutritional benefits of a food substance.

The carbohydrate content of a food material indicates how much of the energy-yielding biomolecules that it contains. Carbohydrates are a class of nutrients which are vital for providing much of the biochemical energy for metabolic, physiological, and cellular biosynthesis, growth, and development. In the present study, it was observed that the cotyledon of *C. albidum* had more carbohydrate content than the flesh of the fruit part. This is expected as the cotyledon is a reservoir for stored nutrients especially starch, which is necessary for the survival of the plant upon germination and even through dormancy. The findings also were lower than that reported by Gabriel *et al* [33], Akubor *et al* [34] and Damilola *et al* [35]. However, these values were found to be in close range indicating the presence of carbohydrates at varying amounts based on differences in analytical methods or experimental procedures. The flesh also contained considerable amounts of carbohydrates explaining why the fruit can serve as an instant fruit snack and immediate source of energy. The work further shows both parts of *C. albidum* to be excellent sources of carbohydrates and other proximate factors.

C. albidum showed significant presence of mineral elements such as sodium, potassium, iron, magnesium, selenium, calcium, and zinc, both in the flesh and cotyledon. The presence further suggests the plant to be a viable source of mineral nutrients for the body's various metabolic and physiologic processes, including maintaining muscle tone and body's electrolytes thus attesting to its nutritional value [35]. Sodium (Na) was found to be higher than all the minerals determined in the present study. Cotyledon sodium was significantly higher than the flesh and agrees with the work of Asare *et al* [30] and Ukana *et al* [26] who also compared and reported lower Na values for both pulp and cotyledon. Sodium is essential to nerve impulse transmission and the principal extracellular cation. The recommended daily allowance of sodium as put forward by World Health Organization is below 2 gram of salt per day [36], which is within acceptable recommended levels based on the finding of this work.

The potassium content of both cotyledon and pulp were found to be within close range though

higher in the flesh. This finding was in consonance with those reported by Asare *et al* [30] and Ukana *et al* [26]. Potassium plays an important role in the human body and sufficient amounts in the diet protect against heart disease, hypoglycemia, diabetes, and obesity. Adequate intake of this mineral from diets has been found to lower blood pressure by antagonizing the biological effects of sodium [20, 37]. It is also the principal intracellular fluid cation required for conduction of nerve impulse, muscle contraction particularly the cardiac muscle, and cell membrane function [38].

The magnesium content was determined in the present study to be comparatively higher in the cotyledon than the flesh and it is lower than that reported by Asare *et al* [30] and Ukana *et al* [26] but similar to that reported by Pratap [39] for *Alternanthera brasiliana* leaf. Magnesium is an active component of several enzyme systems [38]. It is required for most biosynthetic processes including glycolysis [39], maintenance of electrical potentials in nerves and muscle and neurotransmission of impulses.

The micronutrients of biochemical interest determined in this present study were zinc, selenium, manganese, and copper. As noted by Asare *et al* [30], zinc content was found to be comparatively higher than that of the present study. Zinc is required for the optimal functioning of many enzymes involved in catalytic and regulatory functions [40] and its presence in both parts of *C. albidum* attest to its beneficial aspects in metabolism. Copper functions as an antioxidant by protecting the brain and the nervous system. Manganese, on the other hand, is necessary as a cofactor for the catalytic function of certain enzymes as well as a functional component of manganese-superoxide dismutase (Mn-SOD), which scavenges reactive oxygen species in mitochondrial oxidative stress [41].

Secondary metabolites or phytochemicals have always indicated the potentials of plants to be relevant in trado-medicinal and orthodox practices for the treatment and amelioration of certain disease conditions. Consequently, their presence in plants is usually determined to suggest their usefulness in averting pathological disease courses. Flavonoids, saponins, tannins, and alkaloids, in both flesh and cotyledon were observed to be similar to those reported by Asare *et al* [30] and Egbunu *et al* [27]. Flavonoids are effective super-antioxidants and free radical

scavengers. They inhibit oxidative cell damage and may contribute to prevent mechanisms of carcinogenesis [42]. Thus, flavonoids in flesh and cotyledon of *C. albidum* promise a viable option in the amelioration of oxidative-related diseases. Alkaloids may be widely useful as cancer chemotherapeutic agents [43]. Tannins have been reported to be anti-carcinogenic and protect the body against cellular oxidative damage. They also inhibit the generation of superoxide radicals [44]. Their presence in both flesh and cotyledon may confer antioxidative properties preventing the initiation of cancer and other degenerative diseases. Saponins have been found to be useful in lowering cholesterol as it binds, limits reabsorption, and facilitates its excretion from the body [29]. They have also been reported to possess anti-inflammatory, hemolytic, and anti-microbial activities [45,46]. Phenols detected in the flesh of *C. albidum* in this study may account for its importance in wound healing especially in the buccal cavity when one is inflicted with scurvy. They also possess the ability to scavenge free radicals through their hydroxyl groups directly contributing to their antioxidant potential [47]. The present investigation thus revealed notable presence of various phytochemicals in appreciable quantities suggesting the plant's therapeutic essence.

The *in-vitro* antioxidant study of *C. albidum* in the cotyledon and flesh showed significant DPPH scavenging, reducing power and increased lipid peroxidation inhibition when compared to butylated hydroanisole (BHA) standard. These properties may be attributed to the presence of phenolic compounds including flavonoids, as have been reported by various authors. Oxidative stress has indeed been implicated in various disease conditions in humans [48] and free radicals have been linked as the major factor responsible for the onset of these pathological ailments such as cancer, inflammation, rheumatoid arthritis, diabetes mellitus among others. Many synthetic food ingredients and environmental xenobiotics can induce a cascade of reactions culminating in production of reactive oxygen species, which may then cause damage to cell membranes and the entire cell. As reported by Egbunu *et al* [27], who studied the antioxidant role of cotyledon endosperm of *C. albidum* in monosodium glutamate (MSG) intoxicated rats, MSG can initiate oxidative stress leading to ROS production and consequently changes in metabolic processes. Thus, the ability of *C. albidum* cotyledon to mop up free radicals may serve a protective effect thereby mitigating

onset of these various ailments. On the other hand, as revealed by the present study, *C. albidum* portends to replace BHA as a viable antioxidant useful in food industries, because of its promising free scavenging ability. BHA is commonly used in food industries, added as a preservative to extend the shelf life of manufactured food items (such as vegetable oils) and prevent oxidative damage [49]. It then becomes imperative to seek new natural alternatives from fruits and vegetables that can serve such industrial purposes as BHA and other synthetic antioxidants may be carcinogenic over long periods of consumption [39]. Hence in this study, both flesh and cotyledon of *C. albidum* were shown to scavenge, reduce and inhibit lipid peroxides and other radicals demonstrating its potential as an antioxidant.

5. CONCLUSION

The proximate, mineral, phytochemical and antioxidant properties of the flesh and cotyledon of *C. albidum* were highlighted in the study. The findings showed significant and considerable amounts of the parameters so far determined. This further revealed *C. albidum* as a fruit plant whose flesh and cotyledon can be exploited for its nutritional and therapeutic values other than the pulp, which is readily consumed for its immediate source of vitamins and sometimes flavour/sweetness. In conclusion, the whole fruit is beneficial for human consumption and should be extensively studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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