

Comparative Analysis of the Proximate and Amino Acids Composition of Skin and Pulp Cuts of *Chrysophyllum Albidum* Fruit Consumed in Southwest Nigeria

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ABSTRACT

Chrysophyllum albidum is a widely consumed fruit in tropical regions, known for its rich nutritional content. The study examined the nutritional values (proximate and amino acids composition) of the skin and pulp cut parts of *Chrysophyllum albidum*. The two cut parts had the following concentrations: proximate (%) [crude fat: 6.88, 4.69; crude protein: 11.2, 16.4; crude fiber: 10.8, 7.12; ash content: 1.93, 2.39; gross energy value (kJ/100g): 1477, 1516], utilizable energy due to protein (UEDP) gave values of 7.73, 11.0 % for the skin and pulp respectively. The coefficient of variation percent (CV %) were generally low with values range between 0.50 – 26.8. Total amino acids (TAA)[97.0 and 86.7 g/100g, total essential amino acids (TEAA), non-essential (TNEAA), protein efficiency ratio (P-PER), isoelectric point (pI), essential amino acid index (EAAI) and biological value (BV) for the skin and pulp cut parts had the following values (g/100g): 34.6 - 36.7, 52.1 – 60.4, 3.03 – 3.87, 4.86 – 5.15, 100- 83.2 and 97.3 – 79.0 respectively. Based on the whole hen's amino acids scoring pattern, 33.3 % of the amino acids scored higher than 1.0, 50 % of the amino acids scored higher than 1.0 based on FAO/WHO essential amino acids scoring pattern, however, scoring based on the amino acids requirements of pre-school child (2 – 5 years) pattern had 77.7 % of the amino acids higher than 1.0 with lysine and methionine were the limiting amino acids in the two samples. Statistical analysis (correlation) showed that no significant difference existed among all the parameters examined. In conclusion, this study established the nutritional values of the skin and pulp of *C. albidum*, highlighting their potentials as valuable dietary sources. The pulp, in particular, stands out for its higher protein and essential amino acid content, making it a potentially beneficial component in diets and food formulations.

Keywords: *Chrysophyllum albidum*, nutritional, essential and non-essential amino acids

INTRODUCTION

The African star apple, locally called Cherry, is in full bloom. You can see the fruits on sale along the highways and roadsides all over the country, especially in the Southern part of Nigeria. *Chrysophyllum albidum* belongs to the family of Sapotaceae. It is popularly called Udara in Igbo, Agbalumo in Yoruba, and Otien in Edo. While many find the taste unpleasant, some find the sticky nature of the inner pulp of the fruit unappealing. The health benefits of cherry are what make it difficult to ignore. Compared with other fruits, cherry is among the healthiest fruits available [2]. It is a dark yellowish fruit with semi-circle seeds, a popular seasonal fruit normally consumed with its flesh because of its sweetness. It is mostly cultivated in rural areas and is very common during the months of December to April. It is a forest fruit tree described by the Scottish botanist George Don. It is commonly found throughout tropical Africa.

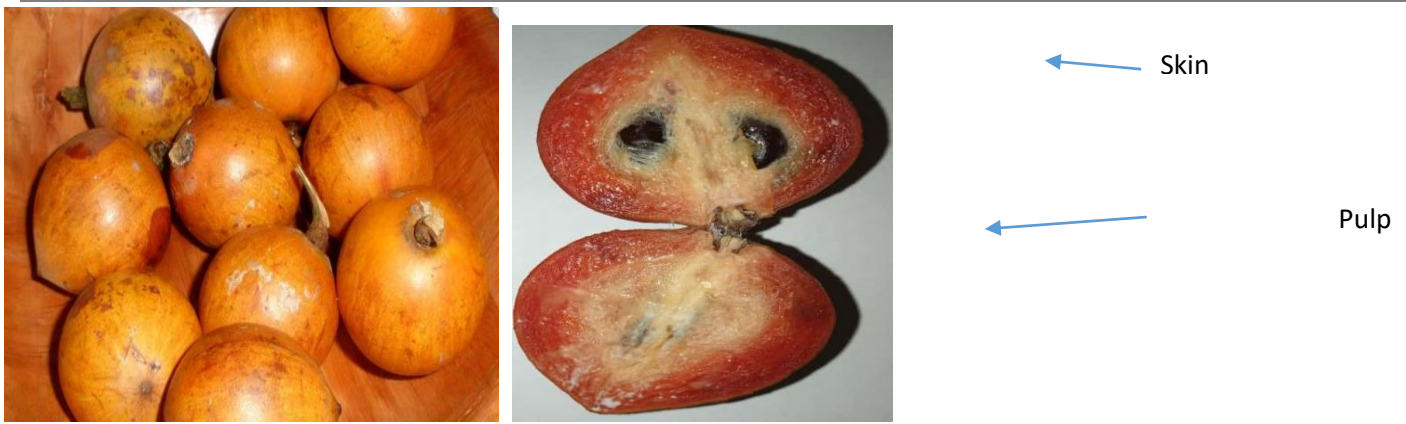


Figure 1: An image of African star apple (*Chrysophyllum albidum*) (African cherry Credit: Healthfacts.ng)

Its distribution extends from Sierra Leone to Spain, and Guinea, extending to Sudan, Uganda, Kenya, and Nyasaino. It is also in countries like Southern Nigeria, Cameroons, Ghana, the Congo Region, and Angola, found in rainforest and transitional formations, often planted for its edible fruits. Its habitat is usually on the riverside in a closed forest, and it is often planted in villages. *Chrysophyllum albidum* has different species, but *Chrysophyllum africanum* and *Chrysophyllum albidum* bear the same common name in Nigeria “UDARA” [3].

A medium-sized evergreen African star-fruits tree usually 70ft to 100ft high; bole straight, fitted, bark grey, and ridges, slash thin, pale brown, darkening to orange, heartwood whitish when first fell turning a pick buff to an olive-yellow and finally to a yellowish brown, not demarcated from the sapwood. Texture fine to medium, grain straight to occasionally interlocked, luster rather low; wood contains a pale brown gum.

Chrysophyllum albidum (African star apple) propagation is by seed either by encouraging natural regeneration or plantation traditionally. The sapwood is pale yellow and takes a good polish. It is fine-grained, hard, and tough and polishes well. It is used in carving and tourney. The seeds yield edible oil, which is sometimes used in Ashanti for making soap. The latex is used as birdlime, the bark is also used medically, often sold in the market and the tree is usually grown for this purpose. The plant recently has become a crop of commercial value in Nigeria. The fleshy pulp of the fruits is eaten especially as a snack and relished by both young and old [4]. The fleshy and juicy fruits, which are popularly eaten, have the potential of a soft drink [3,5]. The fruits are also suitable for the production of fruit jams and jellies [6]. It is reported as an excellent source of vitamins, iron, flavors to diets, and raw materials for some manufacturing industries [7]. The bark, foliage, and fruit of some *Chrysophyllum* species are also used in traditional medicines. It is commercially produced in West Africa [8,9].

In parts of Anambra and Imo States, this tree (African star apple) forms the focal point or venue for a fertility rite, in which young girls and childless wives celebrate a festivity, eating, singing, and dancing for the sole purpose of praying to the gods of birth, this is a gesture of charity since children are freely entertained without discrimination or distinction. The African star apples are valuable sources of minerals such as protein, fat and oil, carbohydrates, etc. [10]. Generally, the African star apple (*Chrysophyllum albidum*) has been described as a widely consumed indigenous fruit across many parts of African countries [6], valued for its sweet/sour taste, and has lots of health benefits [9]. However, with this popularity, there are no sufficient and comprehensive scientific data on its nutritional values especially in terms of amino acid composition. The research, therefore, is conducted to bridge the knowledge gap on the nutritional and amino acids composition of the various cut parts (skin and flesh) of *Chrysophyllum albidum* fruit to enhance its wider applications for dietary, medicinal, and industrial.

Sample Collection

The samples of *Chrysophyllum albidum* used for this research work were purchased from major markets in Ado-Ekiti (Oja Oba, Okesa market, and Mojere) and Iworoko Ekiti.

Sample Preparations

The samples were properly sorted to remove the defective ones, earthen materials and shafts. The skin and pulp of sorted samples were properly air dried for about two weeks using wooden rack in the laboratory. After drying, the samples were milled into fine powder using Exella-Mixer Grinder (3 Jars FSS) and stored in an air tight container.

METHODOLOGY

Proximate Analysis

Moisture content determination

The moisture content was determined using oven-drying method as described by Association of Official Analytical Chemists [11]. Clean and dry petridish was weighed and its weight was recorded (W_1). About 3g of the powdered sample was weighed into the dish. The sample and petridish was weighed and recorded as W_2 . The petridish containing the sample was transferred into the oven maintained at a temperature of 105°C and dried for three hours. The petridish was transferred to the desiccator to cool and the weight was noted. The process was continued until a constant weight (W_3) was obtained. The percentage loss in weight during drying was taken to be the percentage moisture content.

$$\text{Moisture Content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100\%$$

Where,

W_1 = Weight of clean and dry petridish

W_2 = Weight of sample and petridish

W_3 = Weight of sample and petridish after cooling

Ash content determination

The ash content was determined by the method described in AOAC [11]. About 1g of finely ground sample was weighed into clean, dried, pre-weighed crucibles with lid (W_1). The organic matter was burnt off by igniting the sample over a low flame (with lid removed) until the sample became charred. The crucibles were then transferred to the muffle furnace at 550°C (lid removed). The ashing continued until a light grey or white ash was observed. The crucibles were then cooled in a desiccator and weighed (W_2).

The percentage ash content was calculated as follows:

$$\text{Ash Content (\%)} = \frac{W_0 - W_2}{W_0 - W_1} \times 100\%$$

Where,

W_0 = weight of 1g of sample

W_1 = weight of 1g of sample with lid

W_2 = weight of 1g of sample without lid after cooling

Crude fat determination

Semi-continuous solvent extraction method (Soxhlet method) [11] was used for fat determination. About 1g of the sample was weighed into a weighed filter paper and folded neatly. This was put inside a pre-weighed thimble (W_0). The thimble with the sample was weighed (W_1) and inserted into Soxhlet apparatus and extraction under reflux was carried out with petroleum ether ($40 - 60^{\circ}\text{C}$ boiling range) for five hours using a

pre-weighed extraction flask. At the end of the extraction, the extraction flask was removed from the heating mantle when it was almost free of petroleum ether. The extraction flask with the oil was oven dried for about 1 hour at 105°C.

The flask containing the dried oil was cooled in a desiccator and then weighed (W_2). The fat extracted from the sample was then calculated as follows:

$$\text{Crude Fat (\%)} = \frac{W_1 - W_2}{W_1 - W_0} \times 100\%$$

Where,

W_0 = weight of pre-weighed thimble

W_1 = weight of thimble and sample

W_2 = final weight after cooling

Crude fibre determination

2.0g (W_1) of the sample was weighed into one litre conical flask; 200ml of boiling 1.25% H_2SO_4 was added and boiled gently for 30 minutes. The mixture was filtered through muslin cloth and rinsed well with hot distilled water. The sample was scraped back into the flask with spatula and 200ml of boiling 1.25% NaOH was added and allowed to boil gently for 30 minutes. It was filtered through muslin cloth and the residue washed thoroughly with hot distilled water and then rinsed once with 10% HCl, and then followed by acetone. The residue was later scraped into a crucible, dried in an oven at 105°C, cooled in a desiccator and weighed (W_2). The residue was ashed at 550°C for 90 minutes in a muffle furnace. After ashing, it was transferred into the desiccator to cool and weighed (W_3) [12].

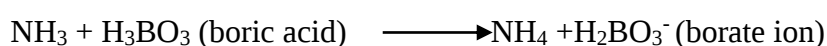
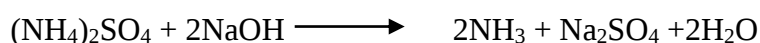
$$\text{Crude fibre} = \frac{W_3}{W_1} \times 100\%$$

Crude protein determination

1.0g of the sample was weighed into a micro-Kjeldahl digestion flask and one tablet of selenium catalyst and 15ml of concentrated H_2SO_4 were added. The mixture was digested on an electro thermal heater until clear solution was observed. The flask was allowed to cool after which the solution was diluted with distilled water to 50ml. 5ml of this was transferred into the distillation apparatus. 50ml of 2% boric acid was pipette into a 100ml conical flask (the receiver flask) and four drops of screened methyl red indicator were added. 50% NaOH was continually added to the digested sample until the solution became turbid, which indicated that the solution had become alkaline. Distillation was carried out into the boric acid solution in the receiver flask with the delivery tube below the acid level. As the process of distillation was still going on, the pink colour solution of the receiver flask changed to blue which indicated the presence of ammonia. The distillation was continued until the content of the round bottom flask was about 50ml after which the delivery of the condenser was rinsed with distilled water. The resulting solution in the conical flask was then titrated with 0.1 M HCl [13].

Equations of reactions and calculation of crude protein

Digestion:



Titration: Borate anion (proportional to the amount of nitrogen) is titrated with standardized HCl.



Calculations:

Moles HCl = Moles NH_3 = Moles N in the sample

A reagent blank should be run to subtract reagent nitrogen from the sample nitrogen

Where:

$$\frac{\text{Corrected acid vol.}}{14} = \frac{\text{Normality of HCl in moles/1000 ml} \times (\text{mL std. acid for sample}) - (\text{mL std. acid for blank})}{14}$$

14 = Atomic weight of nitrogen

A factor is used to convert percent N to percent crude protein. Most proteins contain 16 percent N, so the conversion factor is 6.25 ($100/16 = 6.25$) (Pearson, 1976).

Carbohydrate determination

The carbohydrate content was determined by difference. The percentage carbohydrate content is equal to the sum of the percentages of moisture, ash, fat, fibre and protein content subtracted from 100.

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ Fibre} + \% \text{ Fat} + \% \text{ Protein})$$

Determination of amino acids

The amino acid profile in the *Chrysophyllum albidum* samples was determined using methods described by [14]. The *C. albidum* samples were dried to constant weight. The mass was subsequently defatted, hydrolysed, filtered to remove the humins and evaporated to dryness at 400°C under vacuum in a rotary evaporator. Each residue was dissolved with 5ml of acetate buffer (pH 2.0) and stored in a plastic specimen bottle kept inside the deep freezer pending subsequent analysis. The Technicon Sequential Multisample Amino Acid Analyser (TSM), Technicon Instruments Corporation, New York was used for the analysis. The principle is based on ion-exchange chromatography (IEC) [15]. The uipment is designed to separate free acidic, neutral and basic acids of the hydrolysate. The amount loaded for each sample was 5-10µl and about 76 minutes elapsed for each analysis. The column flow rate was 0.50ml/min at 60°C with reproducibility consistent within $\pm 3\%$. The net height of each peak produced by the chart record of the TSM was measured and calculated for the amino acid it was representing. All chemicals used were of analytical grade.

Estimation of quality of dietary protein: Various methods were used for the above estimation.

I. The essential amino acid score was calculated using the provisional essential amino acid

scoring pattern [16].

II. Amino acid score based on pre-school child essential amino acid requirement for ages 2 –5 years [17].

III. Amino acid score (for both essential and nonessential amino acids) was calculated based on

whole hen's egg [18].

IV. Calculation of essential amino acid index (EAAI) [19].

V. Computation of protein efficiency ratio (C-PER or P-PER) was done using the equation

suggested by [20]:

$$\text{P-PER1} = -0.684 + 0.456(\text{LEU}) - 0.047(\text{PRO})$$

VI. Computation of biological value (BV) was calculated following the equation of [21]

as follows:

a. $BV = 1.09 (EAAI) - 11.73$

b. Where, EAAI = essential amino acid index.

VII. The ratio of total essential amino acid (TEAA) to the total amino acid (TAA), i.e. (TEAA/TAA), total sulphur amino acid (TSAA), percentage (% Cys/TSAA), total aromatic amino acid (TAraA), total basic amino acid (TBAA), total acidic amino acid (TAAA), total neutral amino acid (TNAA) and the Leu/Ile ratios were calculated.

Statistical Analysis

The results were subjected to a Chi-square (χ^2) test on a pairwise comparison according to [22]. The level of significance was determined at $\alpha=0.05$, $df = n-1$ with a critical value of 3.841.

RESULTS AND DISCUSSION

The proximate composition (%), gross energy (kJ/100g) and proportion of energy contributions from macronutrients [protein, fat and carbohydrates (PEP, PEF, PEC)] as well as the utilizable energy due to protein (UEDP) of the skin and pulp of African star apple fruit were depicted in Table 1. The results of the proximate composition (%) (skin and pulp) were: crude fat (6.88 and 4.69), crude protein (11.2 and 16.4), carbohydrates (60.3 and 62.3), ash (1.93 and 2.39), fibre (10.8 and 7.12) and moisture (8.90 and 7.10) with mean values of 5.79, 13.80, 61.3, 2.16, 8.96 and 8.00 respectively. The mean proportion of energy contribution (PEP, PEF, PEC, UEDP and gross energy) were: 15.7, 14.75, 69.7, 9.38 and 1497 with CV% ranged from 0.50 – 31.70.

The proximate composition of skin and pulp of *Chrysophyllum albidum* reflects their unique biochemical composition and varying roles in human and animal nutrition. The skin (8.90 %) and pulp (7.10 %) had moderate moisture contents. High moisture levels in any food sample contributes to their perishability, as reported by [23] for avocado and [24] for garlic. In contrast, averagely low moisture contents observed in the present report may likely enhance their shelf stability, which is in agreement with findings by [25]. The pulp showed a higher ash content (2.39 %) than the skin (1.93%), indicating a richer mineral/inorganic composition. Similar trends of results were reported by [26] for turmeric and [27] for garlic.

Table 1. Proximate composition (%) and proportion of energy contributions of *Chrysophyllum albidum* parts

Parameter	Skin	Pulp	Mean	SD	CV%	χ^2	CrV	R
Crude fat	6.88	4.69	5.79	1.55	26.8	0.414	3.841	NS
Crude protein	11.2	16.4	13.8	3.67	26.6	0.980	3.841	NS
Carbohydrate	60.3	62.3	61.3	1.41	2.30	0.033	3.841	NS
Ash content	1.93	2.39	2.16	0.330	15.3	0.049	3.841	NS
Crude fibre	3.75	4.12	3.94	0.260	6.60	0.017	3.841	NS
Moisture	15.9	10.1	13.0	4.13	31.7	1.310	3.841	NS
% PEP	12.9	18.4	15.7	3.88	24.8	0.966	3.841	NS
% PEF	17.7	11.8	14.75	4.17	28.3	1.180	3.841	NS
% PEC	69.4	69.9	69.7	0.350	0.50	0.002	3.841	NS
UEDP %	7.73	11.0	9.38	2.33	18.0	0.580	3.841	NS
Gross energy	1477	1516	1497	27.6	1.84	0.508	3.841	NS

SD= standard deviation, CV = coefficient of variation, χ^2 =Chi-square, CrV=critical value at $r=0.05$, $df=n-1$, R= remarks, NS=not significant

The pulp (16.4%) was observed as the more protein-rich sample compared to the skin (11.20%). The pulps's high protein content agrees with USDA data and research by [23], emphasizing its rich nutritional value. Skin's lower protein content reflects its primary function as a flavoring agent rather than a protein source. The skin had a higher fat content (6.88 %), which is an indication of rich fatty acids and this is in consonance with the reported by [28] in which avocado's fat content indicated rich monounsaturated fatty acids (MUFA). Pulp's had lower fat content (4.69 %), emphasizing their suitability for low-fat diets. The skin exhibited higher fiber content (10.8 %) than pulp (7.12 %), confirming its role in promoting digestive health, as observed by [29]. This report is in close comparison with the observation of [30] for *Corchorus olitorius* family and [31] for Turmeric powder. (47.30%) and garlic (26.40%) showed higher carbohydrate levels than avocado (8.10%). The two samples (skin and pulp) had moderately high levels of carbohydrates (60.3 and 62.3 %, with a CV % of 2.30). These align with their carbohydrate-rich profile as an indication of energy contribution, as noted in a study by [32] and [33].

The total energy density for each sample was also shown in Table 1. Both crude fat and protein contributed low values into the energy density whereas carbohydrate contributed very high percentage. The total energy density (kJ/100g) in the samples appear thus: Skin (1477) with percentage contribution of 12.9% (protein), 17.7% (crude fat) and 69.4% (carbohydrate) and in the pulp, total energy was 1516 having a distribution of 18.4% (protein), 11.8% (fat) and 69.9% (carbohydrate). On the whole CV% showed that the energy values were close. CV% range was 0.5- 28.3. The total energy values of 1477 – 1516 kJ/100g were close to the literature energy ranges of cereals put at 1.61-1.71 MJ/100g [34] and *Callinectes latimanus* (1142 kJ/100g) [25]. Carbohydrate contains mostly glucose and gives the quickest form of energy. The body has the capacity to change 100% carbohydrate to glucose [30]. The utilizable energy due to protein (UEDP %) was low at 7.73 -11.0, assumption of 60% of protein utilization. This is in agreement with the recommended safe level of 8% for adult man that requires 55 protein per day with 60% utilization [36]. This is apparently high enough to prevent energy malnutrition in children and adults that depend solely on *Chrysophyllum albidum* as the main protein source.

The recommended PEF% from food sources is 30% of the total energy requirement [37] or the value of 35% [38] for total energy intake. The present PEF% value of 11.8 17.7 were much lower compared to the two extreme energy levels. This might be an advantage and useful to people wishing to adopt the guidelines for a healthy diet [30, 35].

Table 2 shows the amino acid (AA) composition for each sample. Glutamic acid had the concentration of 14.88 and 19.65 g/100g crude protein in the skin and pulp cuts of *C. albidum* respectively. On the other hand, Leucine, an essential amino acid was the second highest concentrated amino acid in the two samples with the values of 8.29 and 10.1 g/100g cp respectively. Phenylalanine was the third highest concentrated in the pulp (7.62g/mg), closely followed by proline with a value of 7.60g/100g and then aspartic acid (7.43). Similar trend was also seen in the skin (3rd: aspartic acid (7.42 g/100g); 4th: Proline (6.30g/mg)). In the two samples, amino acid with the least concentration was tryptophan with values of 1.20 and 1.09g/100g respectively for skin and pulp of *C. albidum*. The CV% of the amino acid values were generally low (0.003 - 29.4%) except for lysine (48.6%). The low values of the CV% indicates closeness of the amino acid values in the two samples of *C. albidum*. The total amino acid (TAA) values were: Skin (86.7) and pulp (97.0) g/100g cp.

The levels of glutamic acid (a non. essential amino acid) were comparably lower than those reported for roasted cocoa, cocoa nibs and shell (5.50 - 12.7g/100g cp) [35]., *A hybridus*, *T. occidentalis* and *S. aethopicium* (11.20 - 12.57 g/100 g cp) [39] and traditionally consumed six world vegetables (*C. hirsuta*, *M. perpusilla*, *C. simensis*, *P. chinensis*, *I. javanica* and *P. perfoliatum* from Assim, India (0.02 - 0.75 mg/100g DW) [40]. The levels (g/100g cp) observed for leucine, isoleucine, methionine, lysine, arginine, phenylalanine and tryptophan in the two samples of *C. albidum* (8.29 and 10.1; 3.05 and 3.65; 1.31 and 1.76, 4.62 and 1.92, 4.14 and 4.20, and 7.62 and 1.20 and 1.09) were comparable to the values reported for some fruits, vegetables and starchy roots for use in inherited metabolic disorders [40] and plant foods used in the dietary management of inherited amino acid disorders [41]. The level of value in the samples were Skin (3.98 g/100g), and pulp (3.60g/100g).

These values were comparably close to the values reported for *A. hybridus*, *T. occidentalis* and *S. aethopicum* [39], Ten indigenous leafy vegetables of south west Nigeria [42], pigeon pea [43] and raw, boiled and roasted *Treulia african* seeds flour [[44] The fairly high content of value in the skin and pulp of *C. albidium* are noteworthy because value intervenes drastic reduction of dietary protein allowing a perfect balance of essential amino acid [45]. Also, it is suggestive that *C. albidium* fruits (skin and pulp) could be used in diets of children (2 - 5years) as well as in breeding [46]

Table 2. Amino acids composition (g/100g) of Chrysophyllum albidum cut parts

Amino acids	Skin	Pulp	Mean	SD	CV%	χ^2	CrV	R
Glycine	4.36	3.12	3.74	0.879	23.5	0.207	3.841	NS
Alanine	6.89	8.98	7.94	1.47	18.6	0.273	3.841	NS
Serine	4.72	6.25	5.48	1.08	19.7	0.212	3.841	NS
Proline	6.30	7.60	6.95	0.916	13.7	0.121	3.841	NS
Valine	3.98	3.60	3.79	0.269	7.10	0.019	3.841	NS
Threonine	3.03	3.73	3.38	0.498	14.7	0.073	3.841	NS
Isoleucine	3.05	3.68	3.36	0.443	13.2	0.058	3.841	NS
Leucine	8.29	10.1	9.22	1.31	14.2	0.187	3.841	NS
Aspartate	7.42	7.43	7.43	0.003	0.048	0.000	3.841	NS
Lysine	4.62	1.92	3.27	1.92	58.6	1.122	3.841	NS
Methionine	1.31	1.76	1.54	0.314	20.4	0.064	3.841	NS
Glutamate	14.88	19.65	17.26	3.37	19.5	0.658	3.841	NS
Phenylalanine	5.00	7.62	6.31	1.86	29.4	0.545	3.841	NS
Histidine	2.59	1.89	2.24	0.496	22.1	0.110	3.841	NS
Arginine	4.14	4.20	4.17	0.045	1.08	0.000	3.841	NS
Tyrosine	2.57	2.59	2.58	0.018	0.698	0.000	3.841	NS
Cystine	2.38	1.78	2.08	0.419	20.2	0.085	3.841	NS
Tryophtan	1.20	1.09	1.15	0.077	6.71	0.005	3.841	NS
TAA	86.7	97.0	91.9	7.23	7.92	0.576	3.841	NS

SD= standard deviation, CV = coefficient of variation, χ^2 =Chi-square, CrV=critical value at $\alpha=0.05$, $df=n-1$, R= remarks, NS=not significant

The low level of tyrosine in the samples (skin: 2.57 and pulp: 2.59 g/mg cp) were comparably close to some leafy vegetables in West Cote d' ivoire [46] and cocoa nibs and shell [35] Low tyrosine contents may be due to the destruction of this compound by acid hydrolysin and its instability in hydrochloric acid [47]. Evidence from literatures confirmed the level of arginine (4.14 and 4.20 g/mg for skin and pulp) *C. albidium* that is essential for children [48] and reasonable levels were present in the samples. Therefore, any of the two samples will serve as an average source for the amino acid.

The observed values of arginine (Skin: 4.14 and pulp: 4.20 g/100g) at these levels could be explained by its increased level during maturation of the fruits and at the end of its cycle [46, 47,49].

Since lysine is the first limiting amino acid and tryptophan the third for pork [45], *C. albidium* fruits could be used as supplements dietary in pork and poultry feeds [43]. Also the fruit could be used as an ingredient in the production of bread, biscuits and infant flours because cereals are poor in lysine and tryptophan [39, 50]. The

lysine contain (Skin: 4.62 and Pulp: 1.92 g/100g cp) were about one - half to a quarter of the contents of the reference egg protein (6.3g/mg) [48]. The calculated quality parameters of Amino acids composition from the

two samples of *C. albidium* skin and pulp are shown in Table 3. Total essential and non-essential amino acids (52.1 and 60.4) respectively. These values were comparable to some literate values of non-conventional vegetables and legumes sources [35, 51] and cocoa cake samples [52]. The % ratios of TEAA to TAA were 39.9 and 37.9 in skin and pulp respectively. These are lower than that of an egg (50%) [53], 43.6% reported for pigeon pea [54], 43.8% and 37.8% reported for skin and pulp were in perfect agreement with 39% considered to be adequate for ideal protein food for infants [55,56] 26% for children and 11% for Adults [53].

Table 3. Calculate quality parameters of the amino acids of *Chrysophyllum albidum* cut parts

Parameters	Skin	Pulp	Mean	SD	CV%	χ^2	CrV	R
TAA	86.7	97.0	91.9	7.28	7.92	0.576	3.841	NS
TEAA	34.6	36.7	35.7	1.44	4.04	0.058	3.841	NS
%TEAA	39.9	37.8	38.9	1.51	3.89	0.059	3.841	NS
TNEAA	52.1	60.4	56.3	5.83	10.4	0.605	3.841	NS
%TNEAA	60.1	62.2	61.2	1.51	2.47	0.037	3.841	NS
TAAA	22.3	27.1	24.7	3.37	13.65	0.461	3.841	NS
%TAAA	25.7	27.9	26.8	1.55	5.78	0.089	3.841	NS
TBAA	11.4	8.01	9.68	2.36	24.4	0.576	3.841	NS
%TBAA	13.1	8.26	10.7	3.42	32.0	1.092	3.841	NS
TArAA	8.76	11.3	10.0	1.80	17.8	0.322	3.841	NS
%TArAA	10.1	11.7	10.9	1.10	9.99	0.112	3.841	NS
TSAA	3.69	3.54	3.62	0.110	3.04	0.003	3.841	NS
%TSAA	4.25	3.65	3.95	0.420	10.6	0.046	3.841	NS
TNAA	7.75	9.98	8.87	1.58	17.8	0.280	3.841	NS
%TNAA	8.93	10.3	9.61	0.960	9.99	0.096	3.841	NS
P - PER	3.03	3.87	3.45	0.590	17.1	0.102	3.841	NS
Leu – Ile	5.24	6.24	5.86	0.870	14.9	0.090	3.841	NS
pI	4.86	5.15	5.01	0.210	4.19	0.008	3.841	NS
EAAI	100	83.2	91.6	11.9	13	1.541	3.841	NS
BV	97.3	79	88.2	12.9	14.7	1.899	3.841	NS

SD= standard deviation, CV = coefficient of variation, χ^2 =Chi-square, CrV=critical value at $\alpha=0.05$, $df=n-1$, R= remarks, NS=not significant, EAAI= essential amino acid index, BV= biological Value, pI = isoelectric point, P-PER= predicted protein efficiency ratio,

The contents of TSAA of the two samples (skin 3.69 and pulp 3.54) were generally lower than 5.8g/100g cp recommended for infants [53]. The idea protein range of TArAA is 6.8 - 11.8 (USDA, 2015) whereas skin and pulp of *C. albidium* had values of 10.1 and 8.76 and 11.3g/mg cp respectively, indicating that these fruit parts' TArAA fell within the ideal range of protein values. [54] had earlier reported that aromatic amino acid such as tyrosine is a precursor of epinephrine and thyroxine.

The percentage total neutral AA (TNAA) in the samples are skin (8.93) and pulp (10.3), indicating that they form minor component of the total AA. Total acidic AA (TAAA) ranged from 22.3 – 27.1, which was higher

than the % TNAAs, whilst the percent range in total basic AA (TBAA) was 8.26-13.1, which made the third largest group among the samples. The values reported were comparable to what was reported for the testa of African breadfruit seeds flour [56] and 14.5-15.1 % reported for raw, cooked and roasted groundnut seeds flour [52]. Most animal proteins have been reported to give low cystine value and hence, in % cystine in TSAA for example (Cys/TSAA) % were 35.0% in *Archachatina maginata*; 38.8 % in *Archatina achartina* and 21.0% *Limicolaria sp.* Respectively [57]. In contrast, many vegetable proteins contain substantially more cystine than methionine, for example 62.9% in coconut endosperm [58], 44.4% in *Parkia biglobosa* [59]. The present results (79.0, 40.6 and 45.0 % for *Cucurbita maxima*, *A. viridis* and *B. alba*) respectively, were comparable with the values mostly prevalent in plant samples. Although FAO/WHO/UNU did not give any indication of the proportion of TSAA which can be met by cystine in man, for rats, chicks and pigs, the proportion is about 50 % [17]. Information on the agronomic advantages of increasing the concentration of sulphur-containing amino acids in staple foods shows that cystine has positive effect on mineral absorption particularly zinc (Adesina and Adeyeye, 2016) [60]. The P-PER values were higher than 1.21 (cowpea); 1.82 (pigeon pea); 1.62 (millet ogi) and 0.27 (sorghum ogi) and 2.0 (*Parkia biglobosa*) [59]. In the consumption of maize and sorghum, it has been suggested that an amino acid imbalance from excess leucine might be a factor in the development of pellagra [61]. The present report gave the Leu/Ile ratios of 2.71 (*C. albidium* skin), 2.74 (*C. albidium* pulp) with difference (Leu - Ile) of 5.24 and 6.24 respectively. Clinical, biochemical and pathological observations in human and rats' experiments showed that high Leu in the diet impairs the metabolism of Try and niacin and is responsible for the niacin deficiency in sorghum eaters. High Leu is also a factor contributing to the pellagra-genic properties of maize. Excess Leu could be counteracted by increasing the intake of niacin or Try and also with supplementation with Isoleucine. The Leu/Ile balance is more important than dietary excess of Leu alone in regulating the metabolism of Try and niacin and hence, the disease process [61]. The present Leu/Ile ratios were low in value. Also the present leucine values were less than 11.0g/100g cp; with actual range of 8.29 – 10.1 g/100g cp, and could be beneficially exploited to prevent pellagra in endemic areas. The isoelectric points (pI) as calculated for the amino acids were 4.86 (*C. albidium* skin) and (*C. albidium* pulp). The total neutral amino acids has pI of 5.0-6.3, the TAAA has pI of 3.0-3.1 whilst pI for TBAA is 7.6-10.8. [62] used this method to predict pI of legume and oilseed proteins from their AA in with the overall average percentage deviation was 23.3. This method is therefore, a good starting point in order to enhance a quick precipitation of protein isolate from a biological sample. During experiments on food functionality, one of the important parameters usually studied is the protein solubility of the sample. From such works the minimum solubility is normally observed. The information on minimum protein solubility is important in the preparation of protein isolates; thus, the calculation of pI from the amino acids would give a rough estimate of the pH to prepare the protein isolate of an organic substance without necessarily going through protein solubility determination.

The predicted protein efficiency ratios (P-PER) were 3.03 (*C. albidium* skin) and 3.87 (*C. albidium* pulp). These values compared favourable with 3.55 (unfermented cocoa) but higher than 2.55 (fermented cocoa) nibs, also higher than in the raw and heat-treated samples of *T. africana* seeds flour [63]. According to Muller and Tobin [64], the experimentally determined PER usually ranged from 0.0 for a very poor protein to a maximum possible of just over 4.0. These results show that both *C. albidium* skin and pulp may likely be better utilized in the body compare to other samples in the cited literatures.

The essential amino acid index (EAAI) of the present sample ranged from 83.2 – 100 with CV% (13.0). EAAI is useful as rapid tool to evaluate food formulations for protein quality [65] although it does not account for difference in protein quality due to various processing methods or certain chemical reactions [19]. The EAAI of defatted soybean is 1.26 [19]. The Biological Value (BV) values were as follows 97.3 (*C. albidium* skin) and 79.0 9 *C. albidium* pulp). BV is a scale of measurement used to determine what percentage of a given nutrient source is utilized by the body. The theoretical highest BV of any food source is 100%. In essence, BV refers to how well and how quickly your body can actually use the protein you consume (foodinfo.net/uk/protein/bvi/htm). The BV is very important for vegetarians and vegans, who do not consume animal protein. Plant proteins generally have lower content of some EAA such as Lys and Met. Some literature biological value of some foods can be seen below: whole egg (93.7), milk (84.5), fish (76.0), beef (74.3), soybeans (72.8), rice, polished (64.0), wheat, whole (64.0), corn (60.0) and beans, dry (58.0) (foodinfo.net/uk/protein/bv.htm). The present results in *C. albidium* were better than all of the literature values.

The amino acids scores (AAS) based on whole hen's egg scoring pattern were shown in Table 4. Proline has the highest score in the two samples (1.66 and 2.00 for skin and pulp respectively). Histidine (His) with a score value of 1.08 (*C. albidium* skin) and 0.788 (*C. albidium* pulp) is a semi-essential amino acid particularly useful for children growth. The score is averagely better than 75 % of other amino acids in the two samples. The limiting amino acid in the samples was valine in *C. albidium* skin (0.531) and lysine (0.309 in *C. albidium* pulp). The correction ratio for the whole AA in *C. albidium* would be $100/53.1 \times C. albidium$ protein and $100/30.9 \times C. albidium$ protein in order to bring all the EAA to the required standards when they serve as sole sources of protein. Lysine was limiting in the pulp with a score value of 0.348 and Threonine with a score value of

Table 4. Amino acid scores of *Chrysophyllum albidum* parts based on whole hen's egg amino acid profile

Amino acids	Skin	Pulp	Mean	SD	CV%
Glycine	1.45	1.04	1.25	0.207	16.6
Alanine	1.28	1.66	1.47	0.193	13.1
Serine	0.597	0.791	0.694	0.097	13.9
Proline	1.66	2.00	1.83	0.170	9.31
Valine	0.531	0.480	0.505	0.025	5.01
Threonine	0.594	0.732	0.663	0.069	10.4
Isoleucine	0.545	0.657	0.601	0.056	9.32
Leucine	1.00	1.22	1.11	0.112	10.1
Aspartate	0.694	0.694	0.694	0.000	0.03
Lysine	0.746	0.309	0.527	0.218	41.4
Methionine	0.411	0.549	0.480	0.069	14.5
Glutamate	1.24	1.64	1.44	0.199	13.8
Phenylalanine	0.980	1.49	1.24	0.257	20.8
Histidine	1.08	0.788	0.935	0.146	15.6
Arginine	0.678	0.689	0.683	0.005	0.77
Tyrosine	0.641	0.648	0.645	0.003	0.50
Cystine	1.32	0.990	1.15	0.165	14.3
Tryptophan	0.668	0.607	0.638	0.030	4.75
Total	0.868	0.971	0.920	0.052	5.60

Table 5. Essential amino acid scores of *Chrysophyllum albidum* parts based on FAO/WHO (1973) standards

Amino Acids	Skin	Pulp	Mean	SD	CV%
Valine	0.796	0.720	0.758	0.038	5.01
Threonine	0.757	0.933	0.845	0.088	10.4
Isoleucine	0.763	0.919	0.841	0.078	9.32
Leucine	1.18	1.45	1.32	0.132	10.1
Lysine	0.841	0.348	0.594	0.246	41.4

Methionine + Cystine	1.05	1.01	1.03	0.021	2.06
Phenylalanine + Tyrosine	1.26	1.70	1.48	0.221	14.9
Tryophtan	1.20	1.09	1.15	0.055	4.75
Total	0.909	1.05	0.981	0.072	7.36

Table 6. Essential amino acid scores of *Chrysophyllum albidum* based on requirements of pre-school child (2-5 years)

Amino Acids	Skin	Pulp	Mean	SD	CV%
Valine	1.14	1.03	1.08	0.054	5.01
Threonine	0.891	1.10	0.994	0.104	10.4
Isoleucine	1.089	1.31	1.20	0.112	9.32
Leucine	1.257	1.54	1.40	0.141	10.1
Lysine	0.797	0.330	0.564	0.233	41.4
Methionine + Cystine	1.48	0.395	0.935	0.540	57.8
Phenylalanine + Tyrosine	1.20	1.62	1.41	0.210	14.9
Histidine	1.37	0.996	1.18	0.185	15.6
Tryophtan	1.09	0.994	1.04	0.050	4.75
Total	1.12	1.17	1.15	0.026	2.30

0.757 in *C. albidum* skin as shown in Table 5 according to the essential amino acids scoring pattern given by [17] and in Table 6, the limiting amino acid was also lysine with a score value of 0.330 in the *C. albidum* pulp. On average basis, lysine was limiting according to both [17] and pre-school child (ages 2 – 5 years) scoring patterns. In essence, this indicate that lysine would require correction if *C. albidum* is ton consumed as a sole source of protein in the diet.

The statistical analysis (Chi-Square) χ^2 ($\alpha=0.05$, $df=n-1$) showed that on pairwise comparison there is no significant difference between proximate and amino acids composition of *C. albidum* skin and pulp.

CONCLUSION

From the results obtained from this study, fruit of *C. albidum* (skin and pulp) commonly consumed across Nigeria, are richly endowed with numerous essential nutrients and amino acids. The statistical analysis (Chi-Square: χ^2) showed that no significant differences existed between all the parameters analyzed and quality parameters calculated from the amino acid profiles. Therefore, partial replacement of animal or human foods with *C. albidum* fruit (skin and pulp) or its direct consumption could improve the nutritional status of amino acids in the diets of people in developing countries.

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