

Influence of freezing and oven air drying on the total monomeric anthocyanins, vitamin c and antioxidant capacity of African star apple

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ABSTRACT: African star apple is a good source of vitamin C and antioxidants. The choice of method for preserving its antioxidant properties is a major decision. The aim of this study was to determine the proximate composition, physical properties, total monomeric anthocyanins contents, vitamin C and antioxidant capacity of different parts (the pulp, the seed, and the peel) of the African star apple fruit depending on the method of preservation in the process of freezing, and oven air drying. During oven air drying and freeze drying, losses of vitamin C as compared with fresh fruit parts resulted averagely in 67% and 13% respectively for the seeds, 19% and 4% for the pulp. Freeze drying process was characterized as the best preservation method to contain relative amount of anthocyanins, vitamin C and antioxidants.

Keywords: Antioxidant, freeze drying, oven air drying, vitamin C.

INTRODUCTION

Several investigations have been conducted on fresh fruits and they have been shown to be a major source of dietary fibers, minerals as well as important vitamins such as vitamin C and vitamin E (Ibrahim et al., 2017). The health benefits associated with consumption of those foods are mainly attributed to their phytochemicals, especially polyphenolic compounds (Dauchet et al., 2006; Joshipura et al., 2001). Prevention experts in chronic non-communicable diseases such as coronary heart disease, cancer, stroke, recommended that consumption of fruits and vegetables should most time be in an amount not less than 400 g daily per person (Pomerleau et al., 2005).

African star apple (*Chrysophyllum albidum*) is an indigenous and edible tropical fruit plant that belongs to the family *Sapotaceae* and usually classified as a wild plant. *C. albidum* is seasonal, usually between December and March. It is glaborous when ripe, globose, pointed at the apex, and up to 2 to 4 inches in diameter (Boning, 2006). *C. albidum* is associated with the dry season and commonly found throughout tropical Africa, in various eco zones in the Central, Eastern and Western Nigeria, Uganda, Ghana, Niger, Cameroon, and Cote d'Ivoire

(Ibrahim et al., 2017).

In Ghana it is popularly called Alasa. In Nigeria, the fruit is known as "Agbalumo" by the Yorubas, "Utieagadava" by the Urhobo, "Ehya" by the Igalas, "Agwaluma" by the Hausas and it is called "Udara" by the Efik, Ibibio and other parts of South Eastern Nigeria. Its rich sources of natural antioxidants have been established to promote health by acting against oxidative stress related diseases such as diabetics, cancer and coronary heart diseases (Burits and Bucar, 2000).

Chrysophyllum albidum has recently received considerable attention, not only due to its taste but mainly due to its high antioxidant capacity, presence of polyphenols, vitamin C and potential health benefits (Lichtenthaler et al., 2005; Manganaris et al., 2014). Its pectin value is high (Ige and Gbadamosi, 2007) and thus suggested for its various medicinal purposes, which include reduction in plasma cholesterol level, rate of sugar uptake as well as its detoxifying action and effectiveness in diarrhea therapy (Hulme, 1970).

The fruit has a high nutritional value and is rich in polyphenolic compounds (Lichtenthaler et al., 2005;

Menezes et al., 2008b; Schauss et al., 2006). Phenolic compounds are responsible for major organoleptic characteristics of plant-derived foods and beverages, particular taste and color properties. Polyphenols can prevent cardiovascular diseases effectively (Andrzejewska et al., 2017). Iron and vitamin C are both micronutrients that are prevalent in the fruit pulp and an excellent source of raw material for industries. Flavors and appearance of berries and their various products are strongly influenced by vitamin C and the anthocyanins which are both important fruit quality indicators. These anthocyanins also possess the high resource potential of plants and natural pigments (Szaloki-Dorko et al., 2015). Tannin, terpenoids, protein, flavonoids, resins and carbohydrates are the phytochemicals reported to be present in *Chrysophyllum albidium* (Luo et al., 2002). The tree bark of *C. albidium* has been observed to cure malaria and fever, the skin when consumed cures or reduces blood sugar, cholesterol and to cure heart diseases. The leaves are most times used to cure stomach ache and diarrhea, and the seeds contain more antioxidants used to cure diabetes and cancers and as well contain more phytochemicals, tannins, calcium, and phosphorus (Einbond et al., 2004). Berries are generally perishable, and due to the seasonal period of harvest, they must be preserved. Chemical composition of berries largely depends on the plant age, harvest time (Andrzejewska et al., 2017), and the preservation methods (Manganaris et al., 2014).

One of the most efficient ways to preserve foods is by drying. Drying reduces product's water activity, which inhibits microbial growth and decreases degradative reactions, resulting in higher stability. Besides, drying results in substantial volume reduction, this facilitates transport and storage (Marques et al., 2009; Maskan, 2001). Hot-air drying is the most extensively used drying method. The process consists of blowing a stream of hot air on top of the product, which results in moisture evaporation. This is the commonest drying method; however, the method involves high temperatures and long processing times, which are known to damage nutritional and sensory properties of foods (Ratti, 2001). Dehydrated African star apple is currently primarily being produced by freeze drying. Freeze dried products are known to have high component quality, since the technique preserves bioactive compounds, color, texture and flavor.

The primary aim of the study is to determine the effect of freeze-drying on the content of vitamin C, total monomeric anthocyanins, and value of the antioxidant capacity of the African star apple, relative to those preserved by oven air drying.

MATERIAL AND METHODS

Sample source

The healthy fruits of *Chrysophyllum albidium* were

collected from cultivated Ikole farmlands with geographical location of 7°47'53.76"N and 5°30'52.17"E, RH (relative humidity) 82% and Average temperature of 28°C.

Sample preparation

The fruits were thoroughly washed with water to remove extraneous materials such as dirt. Analysis of the fresh fruits was carried out at Federal University, Oye-Ekiti, Food Analysis Laboratory within 6 hours after collection, and the fruits were separated into pulp, skin, seed and juice and the rest of the analysis were made just after processing and after a 2-month storage period. The preserved samples were stored in the conditions similar to those like in food processing industry and trade: frozen fruits at -18°C but dried.

Each separate fruit samples were mixed into a homogenous pulp, from which weighed samples were collected for testing the content of anthocyanins and samples for determination of the content of vitamin C were collected and prepared separately.

Oven drying

The samples were divided into two portions. The first portion was oven dried at 55°C for 12 hours. The samples were milled and sieved using laboratory sieve (315 micron mesh size). The samples were packed in air tight container for further analysis.

Freeze drying

The second portion of the samples was freeze dried. The samples were placed in the freeze-dryer for 12 hours at 4°C. Samples were milled and stored in air tight container for further analysis.

Physical properties analysis

The whole fruit shape is shaped like an oval and it has pointed tip (apex). Several physical characteristics like number of seeds per fruits were estimated using counting methods. The volume and the weight of the fruit and its parts were determined using water displacement method and electronic weighing balance respectively. The natural repose position of its height and its diameter at the base were measured with vernier calipers.

Chemical analysis

Moisture

Moisture content was determined by the standard AOAC (2000) official method by drying 1 g (W_1) of the sample in

a hot air-oven (Uniscope, SM9053, England) at $105 \pm 1^{\circ}\text{C}$ until constant weight (W_2) was obtained, the samples were removed from the oven, cooled in a dessicator and weighed. The results were expressed as percentage of dry matter as shown in equation below:

$$\text{M. C} = \frac{W_1 - W_2}{W_1} \times 100$$

Where; M.C = moisture content (%), w_1 = mass of sample before drying (g) and w_2 = mass of sample after drying (g).

Ash

Ash content was determined by the official AOAC (2000) method using the muffle furnace (Carbolite AAF1100, United Kingdom). Two grams (W_3) of the sample was weighed into already weighed (W_2) ashing crucible and placed in the muffle furnace chambers at 700°C until the samples turned into ashes within 3 hours. The crucible was removed, cooled in a desiccator and weighed (W_1). Ash content was expressed as the percentage of the weight of the original sample as shown in equation below:

$$\text{Ac} = \frac{W_1 - W_2}{W_3} \times 100$$

Where: Ac = Ash content (%), W_1 = mass of crucible + ash (g), W_2 = mass of empty crucible (g) and W_3 = mass of sample (g).

Protein

The total protein was determined using the Kjeldahl method (AOAC, 2000). Ground sample (0.20 g) was weighed into a Kjeldahl flask. Ten milliliters of concentrated sulphuric acid was added followed by one Kjeltac tablet (Kjeltac-Auto 1030 Analyzer, USA). The mixture was digested on heating racket to obtain a clear solution. The digestate was cooled, and made up to 75 ml with distilled water and transferred onto kjeldahl distillation set up followed by 50 ml of 40% sodium hydroxide solution, the ammonia formed in the mixture was subsequently distilled into 25 ml, 2% boric acid solution containing 0.5 ml of the mixture of 100 ml of bromocresol green solution (prepared by dissolving 100 mg of bromocresol green in 100 ml of methanol) and 70 ml of methyl red solution (prepared by dissolving 100 mg of methyl red in 100 ml methanol) indicators. The distillate collected was then titrated with 0.05M HCL. Blank determination was carried out by excluding the sample from the above procedure:

$$\text{Cp} = \frac{1.401 \times M \times F(\text{ml titrant} - \text{ml blank})}{\text{sample weight}}$$

Where: Cp = Crude protein (%), M = Molarity of acid used

= $0.05 \left(\frac{\text{mol}}{\text{dm}^3}\right)$ and F = kjeldahl factor = 6.25 (-).

Crude fibre

Crude fibre was determined by AOAC (2000) using 2 g (W_3) of sample. About 200 ml of 1.25 % (v/v) sulphuric acid was added and the flask was placed on a hot plate and boiled for 30 min. The content was filtered using filter paper (Whatman No.1) and the residue on the filter paper was washed with 50 to 70 ml distilled water. The washed residue was transferred back into the flask and about 200 ml 1.25 % (w/v) NaOH was added and boiled for 30 min. The content was then filtered as described earlier and the residue obtained was washed with distilled water and then filtered again using filter paper (Whatman No.1). The residue was then transferred to an ashing dish and dried at 130°C for 2 hours, cooled in a desiccator and weighed (W_1). This was then ashed at 550°C inside the muffle furnace chamber (Carbolite AAF1100, United Kingdom) for 30 min, cooled and reweighed (W_2). The ash obtained was subtracted from the residue and the difference expressed as percentage of the starting material as shown in equation below:

$$\text{Cf} = \left(\frac{W_1 - W_2}{W_3}\right) \times 100$$

Where: Cf = Crude fibre (%), W_1 = mass of crucible with the dried residue (g), W_2 = mass of crucible with the ash (g) and W_3 = mass of sample (g).

Ether extract

Crude fat was determined by the AOAC (2000) method using soxhlet apparatus (Sunbim, India). Approximately 5 g (W_3) of the ground sample was placed into a thimble which was placed inside soxhlet extractor and n-hexane was poured into a pre-weighed round bottom flask (W_2), and extracted with n-hexane, poured into a round bottom flask of known weight (W_2), used to extract the oil from the sample. The extraction was carried out for about 6 hours. The solvent was removed from the extracted oil by distillation. The oil in the flask was further dried in a hot-air oven at 90°C for 30 minutes to remove residual organic solvent and moisture. This was cooled in a desiccator and flask and its content weighed (W_1). The quantity of oil obtained was expressed as percentage of the original sample use as shown in equation (iii) given below:

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

Where: W_1 = weight of flask + oil, W_2 = weight of empty flask and W_3 = weight of sample.

Carbohydrate

Carbohydrate was expressed as a percentage of the

difference between the addition of other proximate chemical components and 100% as shown in equation below:

Carbohydrate = 100 – (protein + crude fat + ash + fibre + moisture)

Extraction for antioxidant properties

Five grams of each sample was dissolved in 100 ml of distilled water and stirred for 30 minutes. The suspension was centrifuged for 30 minutes at 3500 x g. The clear extract was kept in the refrigerator at 4°C for further analysis.

Determination of total phenolic content (TPC) of the extract

The determination of the total phenolic content of the extract was carried out using Folin Ciocalteu's phenol reagent reaction as described by Singleton et al. (1999). The calibration curve solutions were prepared by pipetting 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 ml of garlic acid standard

solution (1.0 mg/ml garlic acid) in triplicates into clean dried test tubes. The sample was prepared by dissolving 10 mg of the extract in 10 ml of distilled water (mg/ml) to make stock sample solution. From the stock, 0.2 ml each of 1 mg/ml was pipetted into clean dry test tubes in triplicates. The test tubes (including standard and samples) were made up to 1.0 ml with distilled water. To each of the test-tube was added 1.5 ml of diluted (1:4 v/v) Folin-Ciocalteu's reagent, incubated at room temperature for 5 mins followed by the addition of 1.5 ml of 10% (w/v) NaHCO₃ solution to give a total volume of 4.0 ml. The reaction mixtures were further incubated for additional 90 minutes and the absorbance was read at 725 nm against a blank in a spectrophotometer (INESA, 75N UV-VIS Spectrophotometer, England) containing all reagents except the standard curve was obtained by plotting absorbance against the concentration. The concentration of the phenolic extract was extrapolated from the standard curve and expressed as milligram gallic acid equivalent per g of extract taking into consideration the dilution factor of the samples (mg GAE/g extract). The value extrapolated from the standard curve gave the concentration in µGgae/ml. The concentration in mg nGAE/g extract was obtained using the equation below:

$$\text{TPC} \left(\frac{\text{mgGAE}}{\text{g}} \right) = \frac{\mu\text{gGAE} \times 1 \text{ mg} \times \text{mL of Solvent used in dissolving the sample} \times \text{dilution factor}}{\text{mL} \times 100\mu\text{g} \times \text{mass of the sample used}}$$

Determination of total flavonoid content

The concentration of the flavonoids in the extract was determined spectrophotometrically according to the procedure of Sun et al., (1999). The extract (0.01 g) was dissolved in 5 ml of methanol and made up to 20 ml to give a final concentration of 0.5 mg/ml. To clean dry test tubes (in triplicate) was pipetted 0.2 ml of working solution of the sample and diluted with 4.8 ml distilled water. To each test tube was added 0.3 ml of 5% (w/v) NaNO₂, 0.3 ml of 10% AlCl₃ and 4 ml of 4% (w/v) NaOH. The reaction mixtures were incubated at room temperature for 15 min. The absorbance was read at 500 nm against reagent blank containing all reagents except the extract or standard solution in the case of standard curve solutions. The standard calibration curve was prepared by pipetting 0.0,

0.2, 0.4, 0.6, 0.8, 1.0 ml of 1 mg/ml catechin (1mg/ml of CATECHIN standard solution) into clean dry test tubes. The volumes were made up to 5 ml with distilled water. To each of the test tubes was added 0.3 ml of 5% (w/v) NaNO₂ and 0.3 ml of 5% (w/v) NaOH. The reaction mixture was incubated at room temperature for 15 min. Absorbance was taken at 500 nm and was plotted against the concentration to give the standard calibration curve. The concentrations of the flavonoids in the extract was extrapolated from standard calibration curve and expressed as milligram catechin equivalent per g of extract (mg CAT/g extract). The value extrapolated from the standard curve gave the concentration in µg CAT /ml. The concentration in mgGAE/g extract was obtained using the equation below:

$$\frac{\text{mgCAT}}{\text{g extract}} = \frac{\mu\text{gCAT} \times 1 \text{ mg} \times \text{mL of Solvent used in dissolving the sample} \times \text{dilution factor}}{\text{mL} \times 100\mu\text{g} \times \text{mass of the sample used}}$$

Determination of antioxidant properties

Antioxidant activity by 2, 2-diphenyl-2-picrylhydrazyl hydrate (DPPH) assay

The radical scavenging activity of the extract was determined using the stable radical DPPH (2, 2-diphenyl-2-picrylhydrazyl hydrate) as described by Pownall et al. (2010). The calibration curve solutions were prepared by pipetting 0.2, 0.4, 0.6, 0.8 and 1.0 mL of ascorbic acid

standard solution (1.0 mg/mL ascorbic acid) in triplicates into clean dried test tubes. Ten milligram (10 mg) of the extract was dissolved in 10 mL of methanol to make 1 mg/mL. Two hundred micro liters (200 µL) of the sample extract were pipetted into clean dried test-tubes in triplicates and made up to 1 mL with methanol (1:4 v/v dilution). To 1 ml of the extract and standard concentration prepared was added 1 mL of 0.3 mM DPPH in methanol. The mixture was mixed and incubated in the dark for 30 minutes. The change in color from deep violet to light

yellow was measured spectrophotometrically (INESA, 752N UV-VIS Spectrophotometer, England, England) at 517 nm against DPPH control containing only 1 mL methanol in place of the extracts. The percentage of inhibition was calculated as followings:

$$\% \text{ Inhibition} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100$$

Where A_{control} is the absorbance of control reaction (containing all reagents except the test compound), and A_{sample} is the absorbance of test compound.

Antioxidant activity by ferric reducing antioxidant power (FRAP)

The principle of FRAP method was based on the reduction of a colorless ferric tripyridyltriazine complex to its blue ferrous colored form due to the donation of electron by antioxidant compounds. The ferric reducing antioxidant power (FRAP) assay was carried out according to the method of (Benzie and strain, 1999). A 300 mmol/L acetate buffer of pH 3.6 (3.1g of sodium acetate and 16 mL of glacial acetic acid were placed inside 1000 mL standard flask and then made up to the mark with distilled water), 10 mmol/L of 2, 4, 6-tris (2-pyridyl)-1, 3, 5- triazine, (3.1 mg/mL in 40 mmol/L HCl) and 20 mmol of ferric chloride were mixed together in the ratio 10:1:1 respectively to give the FRAP working reagent. Ascorbic acid calibrated solutions (0.0, 20.0, 40.0, 60.0, 80.0 and 100.0 $\mu\text{g}/\text{mL}$) were prepared and 50 μL of each pipetted into separate test tubes. Sample (10 mg) each was weighed into 10 mL standard flask dissolved and made up to the mark with distilled water and mixed. 50 μL aliquot of each was pipetted into test tube. FRAP reagent (1.0 mL) was added to the standards, crude extract, and blank (prepared by replacing extract and standard with distilled water). The Absorbance of each of the coloured solutions was taken at 593 nm exactly 10 mins after mixing. Ascorbic acid calibrated curve was obtained by plotting absorbance of the standard against concentration and FRAP was obtained from the curve by extrapolation. The ferric reducing antioxidant power was expressed as mg Ascorbic acid equivalence per gram of extract (mg AAE/ g extract).

Antioxidant activity by metal chelating ability assay

The metal-chelating assay of the extracts was carried out according to the method of Singh and Rajini (2004). Solutions of 2 mM $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ and 5 mM ferrozine was diluted 20 times (1 ml of each of the solutions made up to 20 ml with distilled water separately). Ethylene diamine tetra acetic acid (EDTA) calibration curve solutions were prepared by pipetting 6.25, 12.50, 25.00, 50.00 and 100.00 mg/ml of the standard solution into test tubes. Solution of

the extracts was prepared by dissolving 1g of the polyphenol extracts in 10 ml of distilled water (100 mg/ml). Two hundred microliter of the solution was pipetted and made up to 1 ml with distilled water. To the prepared extracts and standard solutions was added 1 ml $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$. After 5 min incubation, the reaction was initiated by the addition of 1 ml of ferrozine. The mixture was shaken vigorously and after a further 10 min incubation period, the absorbance of the solution was measured spectrophotometrically (INESA, 752N UV-VIS Spectrophotometer, England) at 562 nm. The percentage inhibition of ferrozine- Fe^{+2} complex formations was calculated using the formula:

$$\text{Chelating effect} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100$$

Where A_{control} = absorbance of control sample (the control contains 1 mL each of FeCl_2 and ferrozine, complex formation molecules) and A_{sample} = absorbance of sample.

Antioxidant activity by ferric reducing antioxidant power (FRAP)

The ferric reducing antioxidant power (FRAP) assay was carried out according to the method of Benzie and Strain (1999). A 300 mmol/L acetate buffer of pH 3.6, 10 mmol/L of 2,4,6-tris (2-pyridyl)-1, 3, 5-triazine, (3.1 mg/mL HCL) and 20 mmol of ferric chloride were mixed together in the ratio 10:1:1 respectively to give the working FRAP reagent. Ascorbic acid calibrated solutions (20.0, 40.0, 60.0, 80.0 and 100.0 $\mu\text{g}/\text{mL}$) were prepared and 50 μL of each pipetted into separate test tubes. Polyphenol extract (10 mg) was weighed into 10 mL standard flask and made up to the mark with distilled water. One hundred microliter (100 μL) of the extract was pipetted into clean test tubes and made up to 1 ml. FRAP reagent (1.0 mL) was added to the standards, extract and blank (prepared by replacing extract with distilled water). The solution was mixed together and incubated for 10 min. The Absorbance of each of the coloured solutions was taken at 593 nm in a spectrophotometer (INESA, 752N UV-VIS Spectrophotometer, England) and ascorbic acid calibrated curve was obtained by plotting absorbance of the standard against concentration. The FRAP of the extract was obtained from the curve by extrapolation. Ferric reducing antioxidant power (FRAP) was expressed as microgram Ascorbic acid equivalence per gram of extract (μg AAE/ g extract).

Anthocyanins content

The content of monomeric anthocyanins was determined with the Fuleki and Francis method, consisting in

determination of a difference in absorbance of two buffer solutions with pH 1 and pH 4.5 at wavelengths of 510 and 700 nm according to Giusti and Wrolstad (2001). The initial material was 2 g of pulp, from which anthocyanins were extracted with a mixture of ethanol with HCl (85:15 0.1 N HCl). The results of the study were given in conversion to cyanidin-3-glucoside.

Vitamin C content

The vitamin C content was analyzed with the Till-man's method using the reagent 2,6-dichlorophenol-indophenol. Immediately after obtaining the sample, a random handful of fruits was fragmented in a ceramic mortar and after thorough titration, 1 g of studied pulp was separated. Because titration is a very sensitive method, it was performed by the same team at the same lighting conditions.

Statistical/data analysis

All analyses were performed in triplicates. The results were elaborated statistically with the analysis of variance (ANOVA) using the software STATISTICA 10 (StatSoft, Tulsa, OK, USA). Due to the necessity of meeting the condition of uniformity of results, the analysis of variance was performed separately for fresh and frozen fruits and for dried fruits. The significance of differences was assessed using Turkey's test at $p \leq 0.05$.

RESULTS

Proximate analysis was carried out on African star apple (*Chrysophyllum albidium*) to know the nutritional significance of the fruit parts. Results of physico-chemical analyses of the fresh fruit, freeze-dried and oven dried fruit parts of *C. albidium* are summarized in Table 1.

The moisture content values of the fresh fruit ranged from 57.4 (peel) to 69.0% (pulp). The freeze-dried sample had its moisture ranged between 3.96 to 6.74%. The peel showed the lowest moisture content value (3.96%) for the freeze dried samples and this value was significantly different from that of the pulp (6.74%). For the oven dried samples, the pulp also reviewed to contain the highest moisture content (7.18%) while the peel reviewed to contain the lowest moisture (5.31%) and these values were similar to one another. Crude ash content was lowest in the oven dried pulp sample (2.70%) and was highest in the freeze dried peel (4.30%) sample after drying for 72 hours. The fats value ranged from 2.12 to 7.04% for the oven dried samples. Fat contents were lowest in the peel (2.33%) and highest in the seed (7.99%) for freeze-dried seeds but the fresh sample part (pulp) was noted to be the highest. The carbohydrate and the crude fibre were found

to be high in the oven dried peel (79.73% and 6.29%) respectively. The protein content in the fresh fruit ranged between 6.4 and 8.2% and the protein was high in the fresh fruit pulp (8.2%). The freeze dried samples contained protein content ranged from 3.51 to 7.06% and the oven dried samples contained protein content ranged between 2.90 (peel) to 6.24% (seed).

The results of the physical properties of the fruit and its parts are shown in Table 2. The whole African star apple fruit weight ranged between 31.2 and 57.5 g. The range of values of the height, surface area, bulk density and the diameter of the fruits were 4.3 to 5.2cm, 58.9 to 72.7 cm², 1.6 to 2.0 g/cm³ and 4.2 to 5.3 cm respectively. The volume of the fruit was found to be between 25.1 and 48.2 cm³. The seed (about five) constituted between 24.2 and 27.7 g of the fruit while the pulp and the peel constituted between 52.6 and 55.2 g and 19.7 and 22.5 g respectively.

Table 3 shows the results of vitamin C contents in the African star apple (*C. albidium*) along its hours for both freeze and oven drying. From the results, the African star apple sample contained low vitamin C content as the freeze dried samples ranged from 0.087 to 0.966 mg/g. The oven dried samples had vitamin C contents (seed; 0.033 mg/g, pulp; 0.810 mg/g, peel; 0.533 mg/g). The vitamin C content was highest in the oven dried pulp sample and lowest in the oven dried seed sample.

Result of antioxidant properties, total flavonoid content of the fruit parts are presented in Table 4. Total phenolic content in the freeze dried samples ranged from 315.62 mg/GAE/100g to 1057.50 mg/GAE/100g. TPC in the pulp after drying for 72 hours was found to be the highest (1057.50 mgGAE/100g) among all other fruit parts. TPC in the oven dried samples were noted as seed; 279.79, pulp; 690.99, peel; 308.30 mgGAE/100g respectively. TPC was found to be lowest in the oven dried seed (279.79 mg/GAE/100g).

Both the freeze dried and oven dried samples parts of the African star apple contained similar values of FRAP content, but the pulp and seed recorded significant amount. The freeze dried samples had FRAP content ranged from 124.1 to 175.11 mgAAE/100g while the oven dried samples had FRAP content ranged from 121.17 to 174.05 mgAAE/100g after complete drying for 72 hours each. Metal Chelating Ability (MCA) in the freeze dried samples ranged from 43.53 (seed) to 51.46% (pulp), while the Metal Chelating Ability of the oven dried samples ranged from 42.72 (seed) to 47.13% (pulp). It was recorded that the pulp contained highest amount of MCA and the seed had the lowest amount of MCA even after complete oven and freeze drying process for 72 hours each.

Among the oven dried samples, the peel of the African star apple contained the least DPPH value and the pulp the most. In the oven dried samples, the mean content of DPPH was lower (48.84%) as compared with the freeze dried samples (51.92%).

After the oven drying process of the sample parts, the

Table 1. Proximate composition of samples.

Treatment	Portion Treated	Moisture (%)	Ash (%)	Fibre (%)	Protein (%)	Fat (%)	Carbohydrate (%)
FS	Seed	8.12	3.86	5.88	7.28	8.13	66.73
	Pulp	69	3.1	5.2	8.4	14.3	68.1
	Peel	57.4	5.3	14.3	6.4	12.1	64
FD	Seed	4.75	3.64	6	7.06	7.99	70.56
	Pulp	6.74	3.38	5.75	5.68	3.88	74.54
	Peel	4.3	4.3	6.27	3.51	2.33	79.63
OD	Seed	6.36	2.95	6.17	6.24	7.04	71.24
	Pulp	7.18	2.7	5.67	5.44	3.56	75.46
	Peel	5.31	3.65	6.29	2.9	2.12	79.73

FS = Fresh sample, FD = Freeze dried sample, OD = Oven dried sample.

Table 2. Physical characteristics of *C. albidium* fruit.

Characteristics	Range values
Fruit Weight (%)	31.2-57.5
Pulp Weight (%)	52.6-55.2
Peel Weight (%)	19.7-22.5
Seed Weight (%)	24.2-27.7
No of seed per fruit	3.0-5.0
Fruit Volume (cm ³)	25.1-48.2
Diameter Subscribing Circle (cm)	4.2-5.3
Bulk Density (g/cm ³)	1.6-2.0
Surface Area (cm ²)	58.9-72.7
Height at natural rest position (cm)	4.3-5.2

Table 3. Vitamin C (mg/g) content of samples.

Treatment	Portion Treated	(mg/100g)
FD	Seed	0.087
	Pulp	0.966
	Peel	0.775
OD	Seed	0.033
	Peel	0.533

pulp was characterized by the highest total flavonoid content followed by the the peel, and by the lowest fruit part of the African star apple which was the seed. The freeze dried samples on average contained highest (385.72 mgCAT/100g) amount of total flavonoid content.

DISCUSSION

Proximate composition of African star apple (*C. albidium*)

The three parts of the dried samples of *C. albidium* were

low in moisture content while the fresh fruit parts of the African star apple had high moisture content (Table 1). The high moisture content of the fresh fruit corresponds with the range of values reported for fruits and vegetables (FAO, 1968). The moisture content of the fresh fruit was similar to that of fresh sample (71.85%) of *Chrysophyllum albidium* as reported by Oloyede and Oloyede (2014). Similarly, the values for the fresh fruit parts obtained in this research were also similar to the values reported for raw African star apple fruit (70.50%) (Dauda, 2014). Ibrahim et al. (2017) reported the moisture content values of 5.63±0.24, 7.76±0.15 and 4.80±0.15% for freeze dried seed shell, pulp and peel respectively. These values were similar to the values obtained in this literature for freeze dried fruit parts of African star apple. Moisture content value obtained in this research for fresh African star apple fruit parts were a bit lower when compared to the values reported for fresh varieties of *C. albidium* (*C. Acreanum*; 73.2%, *C. Africanum*; 74.7% and *C. Akusae*; 76.3%) by Adepoju and Adeniji (2012). The moisture content values obtained for the dried African star apple fruit parts (seed, pulp and peel) as recorded in this research were lower than the value reported by Agbabiaka et al. (2013) for dried African star apple which was 14.66%. The difference observed may be due to varietal differences. Moisture content of any food is an index of its water activity and is used as a measure of stability and susceptibility to microbial contamination (Aruah et al., 2012).

The fibre contents of the fresh fruit sample parts were higher than that of fresh *Chrysophyllum albidium* which was 0.40% (Oloyede and Oloyede, 2014). Agbabiaka et al. (2013) reported a fibre content of 1.22% in raw African star apple which was lower than those obtained in this research for dried sample parts of African star apple. The fibre content values for freeze dried seed shell, pulp and peel (10.06±0.14, 9.21±0.19 and 15.57±0.25% respectively) as reported by Ibrahim et al. (2017) were higher than the values obtained in this research for freeze dried fruit parts of African star apple. Adepoju and Adeniji (2012) reported the crude fibre content present in dried varieties of *C. albidium* (*C. Acreanum*; 4.5%, *C. Africanum*; 4.3% and *C.*

Table 4. Total phenolics, total flavonoids and antioxidant properties of samples.

Treatment	Portion Treated	TPC (mgGAE/100g)	TFC (mgCAT/100g)	DPPH (%)	FRAP (mgAAE/100g)	MC (%)
FD	Seed	315.62	128.89	52.82	143.36	43.53
	Pulp	1057.5	769.44	60.95	175.11	51.46
	Peel	347.56	258.84	41.98	124.1	44.81
OD	Seed	279.79	116.68	50.67	143.68	42.72
	Pulp	690.99	650.98	55.7	174.05	47.13
	Peel	308.3	160.21	40.14	121.17	43.35

Akusae; 4.1%) which were lower than the values obtained for both freeze dried and oven dried sample parts. The difference observed may also be as a result of varietal difference between the studied sample and that reported these authors. High fibre content in diets have been reported to result in increased removal of carcinogens, potential mutagens, steroids, bile acids and xenobiotics by binding or absorbing to dietary fibre components and be rapidly excreted (Ayoola and Adeyeye, 2009).

The protein values obtained in this research for fresh fruit parts were found to be lower when compared with results found by other studies (Agbabiaka et al., 2013). Oloyede and Oloyede (2014) reported a lower protein value (0.59%) for dried African star apple when compared to the values obtained for freeze dried and oven dried fruit parts. The protein content values for freeze dried seed shell, pulp and peel as reported by Ibrahim et al. (2017) were 8.66 ± 0.19 , 7.31 ± 0.46 and $6.91 \pm 0.48\%$ respectively. These values were higher than the values obtained in this literature for freeze dried fruit parts of African star apple. The protein value obtained for the dried seed and pulp were high than the value (4.0%) reported by Adepoju and Adeniji (2012) for mean protein value of dried varieties of African star apple fruit. The difference observed may be as a result of varietal difference between the studied sample and that reported by the authors. High protein content is important in the body as it helps in the replacement of worn out tissue and regulation of body metabolism. Protein deficiency causes growth retardation, oedema, muscle wasting, and abnormal swelling of the belly and collection of fluids in the body (Arnarson, 2017).

The fat content of *C. acreanum*, *C. africanum* and *C. Akusae* varieties of *Chrysophyllum albidium* (5.6, 5.5 and 5.5% respectively) obtained by Adepoju and Adeniji (2012) were found to correspond in values the one obtained in this research for both freeze dried and oven dried pulp. Similar values were reported by Ige and Gbadamosi (2007) for fresh African star apple when compared to the values recorded in this literature for fresh sample parts of *C. albidium*. Oloyede and Oloyede (2014) reported a very small fat value in dried *Chrysophyllum albidium* and it was lower when compared to the values for dried sample parts obtained in this literature. The fat values, 8.07, 6.97 and 4.68%, reported by Ibrahim et al. (2017) for freeze dried

seed shell, pulp and peel respectively were higher than the values obtained in this study for freeze dried fruit parts of African star apple.

Value for crude ash found in the fresh sample parts were similar and comparable to the value obtained for fresh *C. albidium* by Jayeoba et al. (2010). Dauda (2014) recorded similar ash value (3.13%) when compared to the ash value recorded in this research. Adepoju and Adeniji (2012) also reported similar ash content from dried sample fruit parts. Ibrahim et al. (2017) reported that the crude ash for freeze dried seed shell, pulp and peel were 2.36 ± 0.07 , 2.29 ± 0.04 and $3.27 \pm 0.13\%$ respectively. These values were similar to the values obtained in this research study for freeze dried fruit parts of African star apple.

Ibrahim et al. (2017) reported that the carbohydrate content for freeze dried seed shell, pulp and peel were $65.22 \pm 0.61\%$, $66.45 \pm 0.65\%$ and $64.70 \pm 0.21\%$ respectively. These values were lower when compared to the values obtained in this research for freeze dried fruit parts of African star apple. Carbohydrate content reported by Ige and Gbadamosi (2007) for the fresh fruit sample parts were similar to the content obtained in this study for fresh fruits of *C. albidium*. Similar and high value was reported by Agbabiaka et al. (2013) for dried African star apple fruit parts. Oloyede and Oloyede (2014) reported a lower carbohydrate content which was not comparable to the value obtained in this research for dried *C. albidium*.

Vitamin C

The vitamin C content of *C. acreanum*, *C. africanum* and *C. Akusae* varieties of *Chrysophyllum albidium* reported by Adepoju and Adeniji (2012) were found to be very high when compared to the values obtained for both freeze dried and oven dried fruit parts obtained in this research. The value of the ascorbic acid obtained in this research work was low when compared to that of African star apple reported by Adepoju (2009). Ibrahim et al. (2017) reported that the vitamin C content contained in freeze dried fruit parts (seed; 0.12 ± 0.01 , pulp; 0.10 ± 0.01 , peel; 0.09 ± 0.01 mg/100g) were lower compared to the values obtained in this research study for freeze dried fruit parts of African star apple. This may be due to the varietal difference and

soil condition of the environment where the fruits were cultivated. Ascorbic acid is one of the major nutrients (source of vitamin C) that are obtained mainly from fruits. Apart from the sweet sensation, aroma and flavor of the ripe fruits, the nutritional point of view should also be of importance to consumers. Vitamin C is highly sensitive to a lot of conditions such as heat, light, oxygen, pH.

Antioxidant properties

The health promoting properties of plant-based foods have largely been attributed to their wide range of phytochemicals (Duke, 1992; Rahmani et al., 2014). The result of antioxidant analysis showed that the phenolic content was concentrated in general in the pulp than the seed and the peel. The phenolic content according to Oloyede and Oloyede (2014) for *C. albidum* was 3146 mg/GAE/100g. This value was higher than the values of phenolic content obtained in this research finding. According to Oloyede and Oloyede (2014), the flavonoid concentrations (mg/100g) in dried *Chrysophyllum albidum* is 840, the value was higher than the flavonoid concentration obtained for dried fruit parts in this research. The difference may also be due to varietal difference. The presence of flavonoids in the edible parts of *C. albidum* fruit agreed with the reports of Ibrahim et al. (2017) who reported the presence of flavonoids, tannins, alkaloids, saponins and terpenoids in the freeze dried pulp of *Chrysophyllum albidum* methanol extract. Flavonoids in fruits are important sources of natural antioxidants that are preferred over synthetic ones as they are less toxic (Ifesan et al., 2013). Flavonoids scavenge free radicals produced by Reactive Oxygen Species (ROS) thereby preventing diseases caused by oxidative stress (Kuraś et al., 2009).

DPPH (2,2-Diphenyl-1-picrylhydrazyl) is widely used to test the ability of compounds to act as free radical scavengers or hydrogen donors, and to evaluate antioxidant activity of foods.

Additional factors which could have an impact are the length of extraction time, the specific reagent used in the assay (the type of applied research protocol), together with other factors such as genetic and environmental diversity (climate, temperature, fertility, diseases and exposure to pests) (Wojdyło et al., 2007).

The obtained result revealed that the fruit seed and peel were very low in antinutritional factors, and possibility of intoxication or malabsorption of nutrients from other sources when large quantity of the fruit is consumed is very much unlikely.

The freeze dried edible parts of *C. albidum* upon quantification by chemical analysis were found to be rich in total phenolic content, total flavonoids, DPPH, FRAP and moderate amount of metal chelating ability indicates that the edible parts of *C. albidum* fruit might possess antioxidant, anti-inflammatory and hypocholesterolemic properties.

Conclusion

Averagely, the highest content of antioxidant properties and vitamin C was found in the freeze dried fruit parts of African star apple. The concentrations were strongly concentrated in pulp and seed of the fruit but rarely on the peel. The pulp, regardless of the preservation method, remained the richest resource of proximate composition, vitamin C and it was characterised by the highest antioxidant capacity.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

- Adepoju, O. T. (2009). Nutrient composition and micronutrient potentials of three locally available wildy-grown fruits in Nigeria. *African Journal of Agricultural Research*, 4(9), 887-892.
- Adepoju, O. T., & Adeniji, P. O. (2012). Nutrient composition and micronutrient potential of three wildy grown varieties of African star apple (*Chrysophyllum albidum*) from Nigeria. *African Journal of Food Science*, 6(12), 344-351.
- Agbabiaka, L. A., Eke, L. O., & Nwankwo, C. F. (2013). Nutrients and Phyto-Chemical Assay of African Star Apple Kernel (*Chrysophyllum africanum*) as Potential Feedstuff in Fish and Livestock Production. *British Journal of Applied Science & Technology*, 3(4), 1215-1219.
- Andrzejewska, J., Sadowska, K., & Kloska, L. (2017). Influence of freezing, lyophilisation and air-drying on the total monomeric anthocyanins, vitamin C and antioxidant capacity of selected berries. *International Journal of Food Science and Technology*, 52, 1246-1251.
- AOAC (2000). Official Methods of Analysis. 13th Edn. Association of Analytical Chemists, Washington, DC, USA.
- Arnarson, A. (2017). Eight signs and symptoms of protein deficiency. *Healthline*. Available at <https://www.healthline.com/nutrition/protein-deficiency-symptoms>.
- Aruah, B.C., Uguru, M. I., & Oyiga, B. C. (2012). Genetic variability and interrelationship among some Nigerian pumpkin accessions (*Curcubitassp*). *Plant Breeding International Journal*, 6, 34-41.
- Ayoola, P.B. & Adeyeye, A. (2009). Proximate analysis and nutrient evaluation of some Nigerian pawpaw seeds varieties. *Science Focus*, 14(4), 554-558.
- Benzie, I. F. F., & Strain, J. J. (1999). Ferric reducing/antioxidant power assay: direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic acid concentration. *Methods Enzymol Journal*, 299, 15-27.

- Boning, C. R. (2006). *Florida's Best Fruiting Plants-Native and Exotic Trees, Shrubs, and Vines*. Pineapple Press, Inc. Sarasota, Florida. p. 199
- Burits, M., & Bucar, F. (2000). Antioxidant activity of *Nigella sativa* essential oil. *Phytotherapy Research*, 14(5), 323-328.
- Dauchet, L., Amouyel, P., Hercberg, S., & Dallongeville, J. (2006). Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies. *The Journal of Nutrition*, 136(10), 2588-2593.
- Dauda, A. O. (2014). Physico-chemical properties of Nigerian typed African star apple fruit. *International Journal of Research in Agriculture and Food Sciences*, 2(1), 2311-2476.
- Duke, J. A. (1992). *Database of Biologically Active Phytochemicals and Their Activity*. Boca Raton, Fla: CRC Press, Pp. 183-191.
- Egharevba, H. O., Ibrahim, J. A., Kunle, O. F., & Gamaliel, K. S. (2015) Sustainable exploitation of African medicinal plants. *International Journal of Bioassays*, 4(12), 4636-4639.
- Einbond, L. S., Reynertson, K. A., Luo X.-D., Basile, M. J., & Kennelly, E. J. (2004). Anthocyanin antioxidants from edible fruits. *Food Chemistry*, 84(1), 23-28.
- FAO (1968). Food and Agricultural Organisation of United Nations: Food composition table for use in Africa. Food and Agricultural Organisation of the United Nations, Rome, Italy.
- Giusti, M. M., & Wrolstad, R. E. (2001). Characterization and measurement of anthocyanins by UV-visible spectroscopy. *Current Protocols in Food Analytical Chemistry*. Available at <https://currentprotocols.onlinelibrary.wiley.com/doi/abs/10.1002/0471142913.faf0102s00>.
- Hulme, A. C. (1970). *The Biochemistry of fruits and their products*. A.C. Hulme (ed) Academic Press, London.
- Ibrahim, H. O., Osilesi, O., Adebawo, O. O., Onajobi, F. D., & Karigidi, K. O. (2017). Nutrients compositions and phytochemical contents of edible parts of *Chrysophyllum albidum* fruit. *Journal of Nutrition & Food Science*, 7(2), 9p.
- Ilesan, B. O. T., Fashakin, J. F., Ebosele, F., & Oyerinde, A. S. (2013). Antioxidant and antimicrobial properties of selected plant leaves. *European Journal of Medicinal Plants*, 3(3), 465-473.
- Jayeoba, O. J., Ige, M. M., Omolaiye, J. A., Gbadamosi, S. O., Ogunbanjo, R. O., & Abiola, I. O. (2010). Chemical composition and physical properties of African star apple (*Chrysophyllum albidum*). *ASSET: An International Journal (Series A)*, 7(1), 37-42.
- Joshiyura, K. J., Hu, F. B., Manson, J. E., Stampfer, M. J., Rimm, E. B., Speizer, F. E., Cloditz, G., Ascherio, A., Rosner, B., Spiegelman, D., & Willett, W.C. (2001). The effect of fruit and vegetable intake on risk for coronary heart disease. *Annals of Internal Medicine*, 134(12), 1106-1114.
- Kuraś, M., Pilarski, R., Nowakowska, J., Zobel, A., Brzost, K., Antosiewicz, J., & Gulewicz, K. (2009). Effect of Alkaloid-Free and Alkaloid-Rich preparations from *Uncaria tomentosa* bark on mitotic activity and chromosome morphology evaluated by Allium Test. *Journal of Ethnopharmacology*, 121(1), 140-147.
- Lichtenthäler, R., Rodrigues, R. B., Maia, J. G. S., Papagiannopoulos, M., Fabricius, H., & Marx, F. (2005). Total oxidant scavenging capacities of *Euterpe oleracea* Mart. (Acai) fruits. *International Journal of Food Sciences and Nutrition*, 56(1), 53-64.
- Luo, X. D., Basile, M. J., & Kennelly, E. J. (2002). Polyphenolic antioxidants from the fruits of *Chrysophyllum cainito* L. (star apple). *Journal of Agricultural and Food Chemistry*, 50(6), 1379-1382.
- Manganaris, G. A., Goulas, V., Vicente, A. R., & Terry, L. A. (2014). Berry antioxidants: small fruits providing large benefits. *Journal of the Science of Food and Agriculture*, 94(5), 825-833.
- Marques, L. G., Prado, M. M., & Freire, J. T. (2009). Rehydration characteristics of freeze-dried tropical fruits. *LWT-Food Science and Technology*, 42(7), 1232-1237.
- Maskan, M. (2001). Kinetics of colour change of kiwifruits during hot air and microwave drying. *Journal of Food Engineering*, 48(2), 169-175.
- Menezes, E. M. D. S., Torres, A. T., & Sabaa Srur, A. U. (2008). Lyophilized açai pulp (*Euterpe oleracea*, Mart.) nutritional value. *Acta Amazonica*, 38(2), 311-316.
- Oloyede, F. M., & Oloyede, F. A. (2014). The antioxidant and food value of *Chrysophyllum albidum* G. Don. *School Journal of Agriculture and Veterinary Science*, 1(1), 1-5.
- Pomerleau, J., Lock, K., Knai, C., & McKee, M. (2005). *Effectiveness of interventions and programmes promoting fruit and vegetable intake*. Geneva: WHO. Pp. 1-113. Available at www.who.int/dietphysicalactivity/fruit/en/. Accessed 10 June, 2016.
- Pownall, T. L., Udenigwe, C. C., & Aluko, R. E. (2010). Amino acid composition and antioxidant properties of pea seed (*Pisum sativum* L.) enzymatic protein hydrolysate fractions. *Journal of Agricultural and Food Chemistry*, 58(8), 4712-4718.
- Rahmani, A. H., Aly, S. M., Ali, H., Babiker, A. Y., & Srikar, S. (2014). Therapeutic effects of date fruits (*Phoenix dactylifera*) in the prevention of diseases via modulation of anti-inflammatory, anti-oxidant and anti-tumour activity. *International Journal of Clinical and Experimental Medicine*, 7(3), 483-491.
- Ratti, C. (2001). Hot air and freeze-drying of high-value foods: A review. *Journal of food Engineering*, 49(4), 311-319.
- Schauss, A. G., Wu, X., Prior, R. L., Ou, B., Huang, D., Owens, J., Agarwal, A., Jensen, G. S., Hart, A. N., & Shanbrom, E. (2006). Antioxidant capacity and other bioactivities of the freeze-dried Amazonian palm berry, *Euterpe oleracea* Mart. (acai). *Journal of Agricultural and Food Chemistry*, 54(22), 8604-8610.
- Singh, N., & Rajini, P. S. (2004). Free radical scavenging activity of an aqueous extract of potato peel. *Food Chemistry*, 85(4), 611-616.
- Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R.M. (1999). Analysis of totalphenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods Enzymology*. 299, 152-178.
- Szalóki-Dorkó, L., Stéger-Máté, M., & Abrankó, L. (2015). Evaluation of colouring ability of main European elderberry (*Sambucus nigra* L.) varieties as potential resources of natural food colourants. *International Journal of Food Science and Technology*, 50(6), 1317-1323.
- Wojdyło, A., Oszmian, J., & Czemerys, R. (2007). Antioxidant activity and phenolic compounds in 32 selected herbs. *Food Chemistry*, 105(3), 940-949.