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Storage effects and the postharvest quality of African star apple fruits (*Chrysophyllum africanum*) under ambient conditions

*Florence Abolaji Bello and Adiaha Abigail Henry

Department of Food Science and Technology, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

*Corresponding Author E-mail: florenceabello@uniuyo.edu.ng; Phone: +234(0)8038578180

Abstract

Fruits constitute an important part of a balanced diet as they are natural sources of food nutrients. Most of the harvested produce ordinarily is left lying on the farm and at home. These plant nutrients degraded shortly after harvesting as a result of biochemical changes. The effect of storage after harvesting on African star apple fruit at ambient temperature ($28\pm 2^{\circ}\text{C}$) was investigated on alternate days (1, 3 and 5). Its pulp, peel and seed were investigated in terms of their proximate composition, vitamin C, mineral elements and antinutrients using standard analytical techniques. The results showed a significant ($p < 0.05$) difference in the percentage proximate composition of African star apple fruit pulp and peel while there was no significant ($p > 0.05$) difference in moisture and crude protein of the seed at the storage days 1, 3 and 5. Greater percentage increase of moisture and crude fat contents were observed in the pulp and peel while there were decreases in the moisture, ash, crude protein and crude fibre contents of the seed in the storage days. The vitamin C content of the African star apple fruit pulp, peel and seed was significantly ($p < 0.05$) different as storage progressed. There was a significant ($p < 0.05$) difference in mineral content of the African star apple pulp, peel and seed. Greater amount of sodium, potassium and magnesium were detected in the seed while pulp contain higher amount of calcium. The antinutrient composition decreased significantly ($p < 0.05$) in the pulp, peel and seed as the days progressed. African star apple fruit has a great potential in improving human health and as supplement in food formulation.

Keywords: Antinutrient, fruit, mineral, star apple, postharvest, proximate.

INTRODUCTION

Food security, health and the socio-economic welfare of both rural and urban communities have been sustained through non-timber forest products such as fruits, seeds, roots, stems, leaves and flowers (FAO, 1989). Fruits constitute important parts of a balanced diet as they are natural sources of food nutrients namely: protein, carbohydrate, minerals and dietary fibre, needed by man and animals. African star apple (*Chrysophyllum africanum*) an indigenous plant is an edible tropical fruit known by various tribal names in Nigeria as *agbalumo* (Yoruba), *udara* (Ibo, Efik and Ibibio), *ehya* (Igala) and *agwaluma* (Hausa). It is classified as a wild plant and belongs to the family, *Sapotaceae*. *Chrysophyllum* is a genus of about 70-80 species of tropical trees native to

tropical regions throughout the world, with the greatest number of species in the Northern South America and some parts of Africa (Arindam *et al.*, 2010). It is a tree with great potentials not only as a plantation species, but also in agro- forestry system (Okigbo, 1978, Okafor, 1981).

African star apple (*Chrysophyllum africanum*) fruit is of great economic value due to its diverse industrial, medicinal and food uses. The fruits are not only consumed fresh but also used to produce jam, jellies, stewed fruit, marmalade, syrup and several types of soft drinks. It is also used for medical purposes due to properties of stalk and fruits. The leaves and seed of some of these fruits and vegetables are used in

pharmaceuticals. Some of the trees are also valuable for ornamentation as an ever green broadleaf plant (Islam, 2002).

Several researchers (Achinewhu, 1983; Edem *et al.*, 1984; Adewusi, 1997; Adisa, 2000; Amusa *et al.*, 2003; Egunyomi, *et al.*, 2005; Akubugwo and Ugboku, 2007; Ugbogu and Akukwe, 2008; Duyilemi and Lawal, 2009; Oboh *et al.*, 2009; Adebayo *et al.*, 2010 and Adewoye *et al.*, 2010) have reported the nutritional and medicinal importance of *C. albidum*. In spite of the wide consumption of this wild fruit and its great contribution to the nutritional intake of Nigerians, its seasonality limits its availability throughout the year coupled with losses shortly after harvesting due to biochemical and microbial changes. This study therefore aims at determining the effects of storage on the nutritional and antinutritional composition of African star apple fruit (*Chrysophyllum africanum*) pulp, peel and seed after harvesting.

MATERIALS AND METHODS

Sample collection and preparation

Fresh, ripe fruits of African Star Apple (ASA) were harvested from a local farm in Uyo, Akwa Ibom State. The fruits were sorted, cleaned and spread on trays for storage at ambient temperature ($28\pm 2^{\circ}\text{C}$) for observation of postharvest changes and determination of nutritional as well as antinutritional parameters on alternate days (1, 3 and 5). The pulp, peel and seed of the ASA fruits were removed and kept separately. The cotyledons (inner portion) of the seed were removed from hard outer shell by cracking manually. The fruit pulp, peel and seed were dried in a hot air oven at 65°C for 17 hours. The dried samples were grounded into flour using pestle and mortar and then sieved through a 40 mesh sieve (British standard). The flours were packaged in air tight plastic containers prior to use. The dried pulp, peel and seed flours were used for proximate, vitamin and antinutrient analyses except for the moisture content which was determined using the fresh fruits.

Determination of Proximate Composition

Moisture content

The moisture content was determined according to the method of AOAC (1995). The weight of a dry sterile evaporating dish was taken after cooling in a desiccator. Five (5) grams of each sample were weighed into pre-weighed dry evaporating dish. The dish and the content were reweighed before placing them in a hot air oven (J.P. Selecta 200/243) at a temperature of 105°C for 3 hours. After drying, the dish and the content were allowed to cool in a desiccator containing silica gel. The dish and

the dry samples were reweighed. The procedure of drying was repeated three times until a constant weight was obtained. The moisture content was calculated as a percentage weight loss after drying as follows:

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

$$\% \text{ Moisture content} = \frac{\text{Weight of original sample} - \text{Weight of dry sample}}{\text{Weight of original sample}} \times 100$$

Ash content

A crucible with lid was ignited in an oven at a temperature of 105°C for 1 hr. It was transferred to a desiccator to cool and weighed. Five (5) grams of finely ground oven-dried sample were placed in a muffle furnace (Nabertherm GmbH 20) at a temperature of 550°C until the sample turned completely into ash. The crucible was allowed to cool to room temperature in a desiccator, reweighed and the weight difference was determined as percent weight loss as follows:

$$\% \text{ Ash} = \frac{\text{Weight of ash} \times 100}{\text{Weight of original sample}}$$

Crude Protein

Crude protein of the samples was determined using Micro-Kjeldahl method according to AOAC (1995).

Digestion

Two (2) ml of the sample was accurately weighed into a standard 250 ml Kjeldahl flask containing 1.5 g CuSO_4 and 1.5g Na_2SO_4 as catalysts and 5 ml of concentrated H_2SO_4 . The digestion flask was placed in the digestion rack and heated gently to avoid frothing for $2\frac{1}{2}$ hr until a clear bluish solution was obtained. The digest was allowed to cool and diluted with 20ml of distilled water and made up to 50 ml.

Distillation

Twenty (20) ml of the digest was transferred into a micro Kjeldahl distillation apparatus with anti-bumping chips, to which 10 ml of 40% NaOH solution was added. The mixture was steam-distilled and the liberated ammonia collected into a 100 ml conical flask containing 10 ml solution of saturated boric acid to which two drops of a mixed indicator had been added. The tip of the condenser was immersed in the boric acid-double-indicator solution. Distillation continued until about two-third of the original volume was obtained.

Titration

The tip of the condenser was rinsed with a few mls of distilled water into the distillate and titrated against 0.1N HCl solution until a purple to pink colour was obtained. A blank determination was similarly carried out as described above. The crude protein was obtained by multiplying the percentage (%) nitrogen content by a factor (6.25) to get the weight of protein.

$$\% N = \frac{\text{Titre value} \times 0.1N HCl \times \text{Atomic mass of Nitrogen} \times \text{Dilution factor} \times 100}{\text{Weight of sample digested (mg)}} \times 100$$

$$\text{Crude Protein} = \% N \times \text{Conversion factor (6.25)}$$

Crude Fat

The method described by AOAC (1995) was adopted. Three (3) grams of the sample were accurately weighed into an extraction thimble which had already been washed and dried in an oven and plugged lightly with cotton wool. Fifteen (15) ml of petroleum ether (boiling point 60-80°C) was poured into a 500 ml capacity round bottom flask placed on a heating mantle. The Soxhlet apparatus was assembled and allowed to reflux for about 4 hours. The weight of the lipid obtained after evaporating the solvent from the extract gave the weight of the lipid present in the samples as follows:

$$\% \text{ Crude Fat} = \frac{\text{Weight of fat} \times 100}{\text{Weight of sample}}$$

Crude Fibre

Crude fibre was equally analysed according to AOAC (1995). Two (2) gram of defatted sample was used for fibre determination. The defatted sample was obtained by extraction of fat material with petroleum ether for 2 hours. The sample was boiled under reflux for 30 minutes with 200 ml of a solution containing 1.25 g H₂SO₄ per 100 ml solution and 1.25 g NaOH solution. The solution was filtered using cotton cloth on a fluted funnel and washed with boiling water until the washings were no longer acidic. The residue was finally washed with methanol and transferred into a pre-weighed crucible and oven-dried at 105°C. The sample was incinerated in a muffle furnace at 500°C, allowed to stand at this temperature 2 hr and later cooled in a desiccator and weighed. The loss in weight after incineration multiplied by 100 gave the percentage of crude fibre as follows:

$$\% \text{ Crude Fibre} = \frac{(\text{Weight of crucible} + \text{sample after incineration}) - \text{Weight of empty crucible} \times 100}{\text{Weight of original sample}}$$

Carbohydrate

The total carbohydrate contents of the samples were determined by difference. The sum of the percentage crude fat, crude protein, ash and moisture content were subtracted from 100%, that is,

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

Estimation of Calorific Value (Energy)

The calorific value of the samples was calculated by Atwater factor method as described by Osborne and Voogt (1978). The value of the protein, carbohydrate and fat was multiplied by 4, 4 and 9 Kcal, respectively and their sum was taken as the total energy.

Determination of Ascorbic acid (Vitamin C)

The titration method was used as described by Osborne and Voogt (1978). One gram (1g) each of sample was weighed into test tubes. 1 ml of ascorbic acid stock standard was pipetted into a separate test tube as a standard. 1 ml of trichloroacetic acid (TCA) solution was placed in another test tube to serve as blank. 10 ml TCA solution was added to the sample tubes. 1 ml of ditrophenyl hydrazine-thiourea-copper sulphate (DTCS) reagent was added to all the tubes and capped. The tubes were incubated in a water bath at 37°C for 3 hours. They were removed from the water bath and chilled for 10 min in an ice bath while shaking slowly, 2 ml of cold 12 M H₂SO₄ was added to all the test tubes. The spectrophotometer was adjusted with the blank to read zero absorbance at 520 nm. The absorbancies of standard and test samples were also read. The results were calculated as follows:

$$\text{Vitamin C (mg/100g)} = \frac{\text{Absorbance of test samples} \times \text{Concentration of standard}}{\text{Absorbance of standard} \times \text{Weight of sample}}$$

Determination of Mineral Elements

Calcium and magnesium were determined using atomic absorption spectrophotometer while sodium and potassium were determined using flame photometer (AOAC, 1995).

Determination of Anti-nutrients

Hydrocyanide

The standard method of AOAC (1995) was used in the determination of hydrocyanide content of samples. Five (5) gram of each samples were soaked in water for 2 hr, after which the liberated cyanide was extracted by steam distillation into 2.5 % w/v NaOH to which 8 ml of 6 N ammonium hydroxide was added. 0.02N silver nitrate

Table 1. Proximate composition of African star apple pulp, peel and seed

Sample	Moisture Content (%)	Ash (%)	Crude Protein (%)	Crude Fibre (%)	Crude Fat (%)	Carbohydrate (%)	Energy (%)
PULP							
Day 1	36.45±0.53 ^c	2.65±0.25 ^c	6.06±0.06 ^b	2.54±0.16 ^e	16.02±0.17 ^b	36.29±0.14 ^{cd}	313.49±0.14 ^c
Day 3	41.60±1.41 ^b	2.91±0.08 ^b	6.31±0.26 ^a	2.71±0.12 ^d	17.72±0.33 ^a	28.65±0.07 ^{de}	299.33±0.14 ^g
Day 5	46.69±1.07 ^a	2.93±0.06 ^b	5.73±0.11 ^c	2.89±0.10 ^c	17.53±0.11 ^a	24.56±0.11 ^e	278.93±0.32 ^c
PEEL							
Day 1	35.31±0.27 ^d	3.67±0.07 ^a	3.88±0.08 ^d	3.67±0.07 ^a	15.25±0.10 ^c	38.19±0.09 ^{cd}	305.61±0.24 ^e
Day 3	37.02±0.03 ^c	3.02±0.08 ^b	3.10±0.05 ^e	2.92±0.07 ^c	15.16±0.09 ^c	38.79±0.17 ^{cd}	303.90±0.25 ^f
Day 5	36.38±0.08 ^c	3.10±0.10 ^b	2.02±0.08 ^g	3.05±0.05 ^b	13.50±0.05 ^d	41.93±1.12 ^c	297.29±0.20 ^h
SEED							
Day 1	28.62±0.08 ^e	1.40±0.05 ^d	2.37±0.08 ^f	1.36±0.05 ^f	7.33±0.07 ^f	58.59±0.40 ^b	310.64±1.48 ^d
Day 3	28.14±0.05 ^e	1.10±0.05 ^e	2.35±0.06 ^f	0.95±0.05 ^g	7.37±0.16 ^f	58.59±0.32 ^b	316.84±0.31 ^d
Day 5	27.78±0.08 ^e	0.80±0.05 ^f	2.45±0.05 ^f	0.78±0.04 ^h	7.80±0.05 ^e	60.39±0.07 ^a	321.57±0.20 ^a

Values represent mean±standard deviation of triplicate determinations on dry matter basis.

Values with the same letter along the same column are not significantly ($p>0.05$) different.

was used to titrate the mixture to an endpoint that is faint but permanently turbid.

Oxalate

Oxalate was determined by the standard method of AOAC (1995). Extraction of 3 g of the samples with water for 3 hours was carried out and 2.5 g chloride was added to the extracted samples. The precipitated oxalate in each sample was separately washed with 25 % sulphuric acid and subsequently dissolved in water before titrating against 0.05N $KMnO_4$ while the absorbance of the extracts was read at 420 nm and the amount of oxalate estimated by extrapolation.

Phytate

Phytate was determined using the method of Sudarmadji and Markakis (1977). Ten (10) grams of sample were weighed into the conical flasks and then extracted with 50 ml of 3 % TCA for 45 min with occasional swirling by hand. The phytate was precipitated as ferric phytate with the solution of ferric chloride. The precipitate was converted to sodium phytate with 3% solution of NaOH before digesting with an acid mixture of equal portion of concentrated H_2SO_4 and 65% ClO_4 . The liberated phosphorus was quantified calorimetrically at 620 nm after colour development with ammonium molybdate to which sodium sulphate and hydroquinone solutions were added.

Tannin

Tannin was determined using the method of Sofowora (1993). Ten (10) grams of dried sample was weighed into a 250 ml conical flask and 50 ml of methanol added. The flask was stoppered, shaken and left to stand for 24 hr. The content of the flask was shaken after extraction while the solid particles were allowed to settle before titration. I

ml portion of the extract of fresh vanilla HCl was added into the volume of extract. The mixture was allowed to stand for 20 min and the absorbance was measured at 520 nm against the reagent blank.

Statistical analysis

The data generated were analysed using Analysis of variance (ANOVA). Significance was accepted at ($p<0.05$). Means that differed significantly were separated using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Proximate Composition of African Star Apple Pulp, Peel and Seed

The effects of storage on proximate composition of ASA pulp, peel and seed in alternate days are shown on Table 1. There were highly significant ($p<0.05$) difference in the pulp, peel and seed of the ASA in alternate days for all the parameters analysed.

Moisture content

The pulp had the highest moisture content in all the storage days when compared to peel and seed. The pulp of day 5 ASA contained 46.69% moisture which was higher than the 41.60 and 36.46% of freshly harvested (day 1) and day 3, respectively. This showed that during storage ripening continued and as the storage days progressed the moisture content of the ASA pulp increased. These values were lower than (66.67%) moisture content reported by Edem and Dosunmu (2011) but higher than the values 31.97 and 35% reported by Chukwumalume *et al.* (2010); Akubor *et al.* (2013) respectively. This trend was observed in ASA peel in all the storage days. There was increase in moisture content

of peel which ranged from 35.31% (day 1) to 37.02% (day 5). There was a lower moisture content compared to 47.95% reported for the peel by Ukana *et al.* (2012) while the ASA seed had the lowest moisture content of 28.62%, 28.14% and 27.78%, respectively as the ripening days progressed. This finding was lower than 20.06% reported by Akubor *et al.* (2013) for the ASA seed. There was no significance ($p>0.05$) difference in the moisture content of the seeds as the day of storage progressed. Low moisture content of the matured seed means it can be stored for a longer period than the pulp and peel because of its better resistance to microbial attack (Ukana *et al.*, 2012).

Ash content

Ash content increased in the pulp with ripening while that of the peel and seed decreased. The ash content of the ASA pulp, peel and seed were 2.65, 2.91 and 2.93%; 3.67, 3.10 and 3.02%; 1.40, 1.10 and 0.80%, respectively. These are respectively close to the values obtained by Ukana *et al.* (2012) for the structural areas studied. The results indicated that the peel had the highest ash content which decreased as the day progressed. Ash content indicates the amount of inorganic matter and oxides present in the sample.

Crude Protein content

The ASA pulp of the days 1, 3 and 5 had the highest protein content of 6.06, 6.31 and 5.73%, respectively, followed by the peel with the values of 3.88, 3.10 and 2.02%, respectively while the seed had the lowest (2.37, 2.35 and 2.45%) as the storage days progressed. There was a significant ($p<0.05$) difference in the crude protein content of the pulp and peel while there was no significant ($p<0.05$) difference in the ASA seed. These values were higher than the crude protein contents of ASA peel, pulp and seed of 6.68, 4.73 and 8.75%, respectively reported by Ukana *et al.* (2012). The low protein content in the samples therefore needs to be supplemented from other sources because protein is useful in the repairing of the worn out tissues, building up of new ones as well as improving the organoleptic properties of food materials.

Crude Fat content

The crude fat content of ASA pulp and seed increased as storage days progressed while that of peel decreased. The ASA pulp had the highest fat content of 16.02, 17.72 and 17.53% which makes it a very good source of energy while the seed had the lowest fat content of 7.33, 7.37 and 7.80%. The fat content of ASA peel decreased as the ripening days progressed (15.25, 15.16 and 13.50%). These values are higher than the corresponding values of 8.94, 10.00 and 3.45%, respectively reported by Ukana *et*

al. (2012). Fat is an excellent source of energy, enhance transport of fat soluble vitamins, protect internal tissues and contribute to important cell processes.

Crude Fibre content

The crude fibre content in the ASA pulp increased after harvesting (2.54, 2.71 and 2.89%). The peel had the highest crude fibre content of 3.67, 3.05 and 2.92% while the seed had the lowest (1.36, 0.95 and 0.78%). These values are lower than 1.83, 3.00 and 2.42%, respectively obtained for the ASA peel, pulp and seed by Ukana *et al.* (2012). The fibre content is an indication that it contains a portion of cellulose, hemicelluloses and lignin. However, low fibre content is also known to reduce the rate of glucose and fat absorption. Hence the low fibre contents in the ASA pulp, peel and seed are advantageous in the absorption of glucose and fat.

Carbohydrate content

The carbohydrate content in the ASA peel and seed increased while these of the pulp decreased with days of ripening. ASA seed had the highest carbohydrate contents of 58.59, 69.93 and 60.39% followed by the ASA peel with the values of 38.19, 38.79 and 41.93% while the ASA pulp had the lowest values of 36.29, 28.65 and 24.56%. The decrease in carbohydrate content of the pulp may be as a result of some enzyme activities on the carbohydrate as the main source of energy during the ripening process.

Energy content

ASA seed contain the highest energy level of 310.64, 316.84 and 321.57% while the pulp had the energy values of 313.49, 299.33 and 278.93% as against the 305.54, 303.90 and 297.29% of the peel as the ripening days progressed.

Vitamin C content of African Star Apple Pulp, Peel and Seed

The day 1 ASA pulp, peel and seed have been found to have the highest vitamin C content of 173.77, 107.33 and 185.63 mg/100g respectively as shown in Figure 1. These values were about 100 times that of oranges and 10 times of that of guava or cashew (Pearson, 1976). The values of vitamin C of ASA were very high when compared with the recommended dietary allowances (RDA), their values exceeding the RDA of 75 mg/day of vitamin C for female and male (Rolfes *et al.*, 2009). The high ascorbic acid content of the fruit was believed to contribute greatly to the acidic taste of the fruit, especially when it is not fully ripe and soft. This shows that the fruit could be used to promote healthy living by protecting the body from scurvy. The result also revealed the decrease

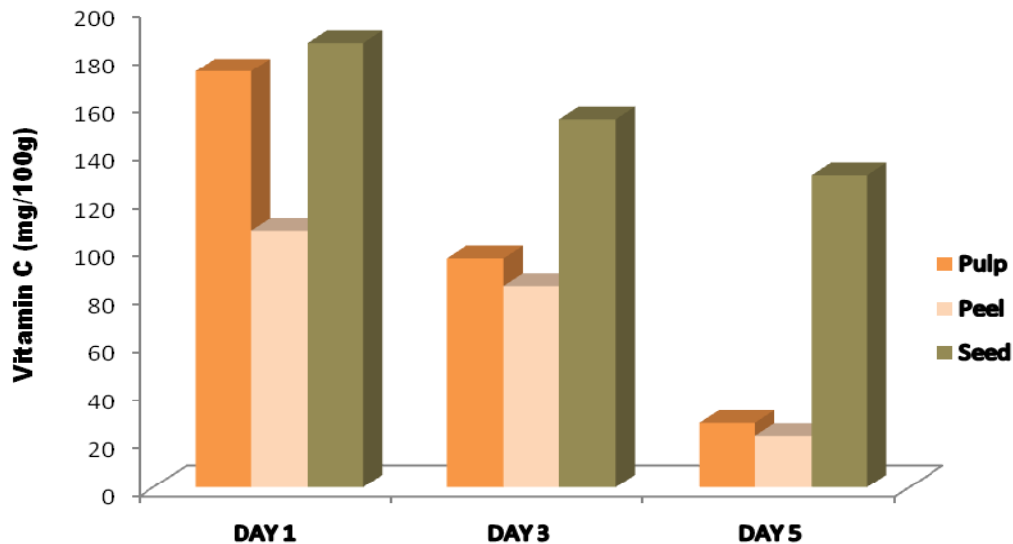


Figure 1. EffectS of postharvest changes on the vitamin C content of African star apple Pulp , peel and seed

Table 2. Mineral composition of African star apple pulp, peel and seed

Sample	Sodium (Na) (mg/100g)	Potassium (K) (mg/100g)	Magnesium (Mg) (mg/100g)	Calcium (Ca) (mg/100g)
PULP				
Day 1	10.77±0.21 ^d	8.60±0.10 ^d	3.50±0.30 ^c	33.00±0.10 ^a
Day 3	10.55±0.61 ^d	9.33±0.16 ^c	3.28±0.30 ^d	30.30±0.10 ^b
Day 5	10.10±0.21 ^e	9.50±0.20 ^c	3.18±0.20 ^c	30.21±0.10 ^b
PEEL				
Day 1	7.03±0.15 ^f	2.18±0.06 ^e	1.83±0.03 ^c	23.16±0.06 ^c
Day 3	7.02±0.07 ^f	2.10±0.06 ^e	1.15±0.05 ^f	23.05±0.05 ^c
Day 5	5.94±0.05 ^g	1.77±0.07 ^f	1.07±0.08 ^f	23.05±0.05 ^c
SEED				
Day 1	24.17±0.16 ^c	23.19±0.16 ^a	13.98±0.14 ^b	20.97±0.15 ^e
Day 3	28.03±0.04 ^b	23.00±0.14 ^a	14.15±0.14 ^b	21.19±0.17 ^d
Day 5	29.21±0.10 ^a	21.23±0.10 ^b	14.79±0.12 ^a	21.03±0.13 ^{de}

Values represent mean±standard deviation of triplicate determinations on dry matter basis. Values with the same letter along the same column are not significantly ($p>0.05$) different.

in vitamin C content of ASA pulp, peel and seed as the ripening days progressed. This trend was similar to the observations of Aydin and Kadioglu (2001) and Othman (2009).

Mineral Composition of African Star Apple Pulp, Peel and Seed

Table 2 presents the results of the mineral analysis. Minerals are very important in the diet because of their diverse functions in the body. They are required for normal growth and other activities of muscles, skeletal development, cellular activity and oxygen transport, chemical reaction in the body and intestinal absorption, fluid balance and nerve transmission, as well as the regulation of acid-base balance.

Sodium (Na) content

The sodium content of the ASA pulp and peel decreased as the day progressed while that of the seed increased. The ASA seed had the highest sodium content of 27.14, 28.09 and 29.21 mg/100g followed by the pulp with values of 10.77, 10.55 and 10.10 mg/100g while the peel had the lowest sodium content of 7.03, 7.02 and 5.94 mg/100g. The mineral is very important in maintaining the body fluid volume, acid-base balance and osmotic equilibrium.

Potassium (K) content

The seed of ASA had the highest potassium content for day 1, 3 and 5 with the values of 23.19, 23.00 and 21.23

Table 3. Antinutritional composition of African star apple pulp, peel and seed

Sample	HCN (mg/100g)	Oxalate (mg/100g)	Tannin (mg/100g)	Phytate (mg/100g)
PULP				
Day 1	ND	2.14±0.15 ^c	0.39±0.13 ^d	0.05±0.07 ^d
Day 3	ND	1.73±0.16 ^d	0.36±0.13 ^d	0.06±0.10 ^c
Day 5	ND	1.64±0.10 ^d	0.31±0.09 ^e	0.08±0.09 ^c
PEEL				
Day 1	ND	4.93±0.14 ^f	0.34±0.17 ^f	0.02±0.10 ^f
Day 3	ND	2.82±0.08 ^g	0.32±0.11 ^g	0.04±0.08 ^f
Day 5	ND	2.10±0.12 ^h	0.32±0.06 ^d	0.05±0.10 ^e
SEED				
Day 1	0.33±0.07 ^a	12.41±0.16 ^a	0.79±0.10 ^a	0.71±0.09 ^a
Day 3	0.31±0.06 ^a	12.40±0.15 ^a	0.78±0.09 ^b	0.69±0.14 ^b
Day 5	0.28±0.06 ^a	11.97±0.64 ^b	0.68±0.09 ^c	0.57±0.14 ^b

Values represent mean±standard deviation of triplicate determinations on dry matter basis. Values with the same letter along the same column are not significantly ($p>0.05$) different.

mg/100g respectively followed by that of the pulp with the values of 8.6, 9.33 and 9.50 mg/100g while the peel had the lowest values of 2.18, 2.10 and 1.77 mg/100g as the ripening days progressed from 1, 3 and 5 respectively.

Magnesium (Mg) content

The magnesium content of ASA pulp and peel decreased as the days increased with the values of 3.50, 3.28 and 3.18 mg/100g; and 1.83, 1.15 and 1.07 mg/100g respectively while that of 13.98, 14.15 and 14.79 mg/100g. The seed had the highest content of magnesium followed by the pulp while the peel has the lowest content of magnesium. These values were lower than 26 mg/kg and 36mg/kg reported by Falade *et al.* (2003) for *C. sinensis* and *A. comusus*, respectively.

Calcium (Ca) content

The calcium content of African star apple increased in the pulp and seed as the days increased with the value of 33.00, 30.30 and 30.21 mg/100g and 20.97, 21.04 and 21.23 mg/100g respectively while the calcium content of the peel decreased with the value of 23.16, 23.05 and 23.05 mg/100g. The peel had the highest content of calcium followed by the seed while the pulp had the lowest.

This fruit has the potentials for providing essential nutrients for human nutrition. Since the nutritional activities of any plant are usually traced to the particular elements it contains (Sofowora, 1993). For example, calcium plays a vital role in the constitution of biological systems; its presence in bones provides an animal with the required rigidity and support (Ibarahim *et al.*, 2006). The level of calcium in this fruit is therefore adequate for the required needs of the body.

Anti-nutritional Composition of African Star Apple Pulp, Peel and Seed

The anti-nutritional composition of African star apple pulp, peel and seed were equally investigated on alternate days of storage and the results calculated in mg/100g, are shown in Table 3.

Hydrocyanide content (HCN)

The hydrocyanide content was not detected in the star apple pulp and peel while that of the seed decreased as the days increased with the value of 0.33, 0.31 and 0.28 mg/100g.

Oxalate content

The oxalate content of the star apple pulp, peel and seed decreased as the postharvest days increased. The seed had the highest content of oxalic acid: 12.41, 12.40 and 11.97 mg/100g, followed by the peel with the values of 4.93, 2.82 and 2.00 mg/100g while the pulp had the lowest (2.14, 1.73 and 1.64 mg/100g). This finding was lower than 4.995 mg/100g (fruit pulp) reported by Edem and Dosunmu (2011).

Tannin content

The tannin content decreased as the day increased in the star apple fruit pulp, peel and seed with the value of 0.39, 0.36 and 0.31 mg/100g; 0.34, 0.32 and 0.32 mg/100g; 0.79, 0.78 and 0.68 mg/100g, respectively. Decrease in tannin content was also reported for guava by Lim *et al.* (2006). The reduction in tannin could be attributed to the action of polyphenol oxidase enzyme which oxidizes tannin to phenol. Tannins adversely affect protein

digestibility but its minimum level required to elicit a negative growth response has not been fully established, hence it is still unclear as to what level of it could be harmful (Elemo *et al.*, 2001). However, the level of tannin content in this fruit pulp and peel is low when compared to that of some other plants (Getachew *et al.*, 2013).

Phytate content

The phytate content increased in the pulp and peel with the values of 0.05, 0.06 and 0.08mg/100g; 0.02, 0.04 and 0.05 mg/100g while that of the seed decreased with the values of 0.71, 0.69 and 0.57 mg/100g as the day progressed. These values were higher than 0.037 mg/100g reported by Adepoju and Adeniji (2012) but lower than 0.32 mg/100g reported by Edem and Dosunmu (2011) for the ASA fruit pulp. The determination of antinutrients in the samples is necessary because their presence can reduce essential nutrients bioavailability. Some of these antinutrients have been found to have protection against some diseases. Phytate has strong binding capacity and forms insoluble complexes with multivalent cations, including calcium, magnesium, sodium and potassium, and thus render them biologically unavailable.

CONCLUSION

The results from the proximate composition showed that the ASA pulp, peel and seed have greater amount of carbohydrate and crude fat contents during storage period but most of the nutrients were concentrated in the pulp and peel. Vitamin C content of the fruit decreased with increased in ambient storage period, this indicated that the quality and shelf life of fruit is hindered at ambient storage. There is a reduction in the antinutrient composition of the ASA pulp, peel and seed with the seed having a moderate amount of antinutrient. The reduction in the antinutrient composition showed that continuous ripening during storage could also be a way of reducing antinutrients in food samples after harvesting. Mineral elements revealed that ASA pulp and peel contain greater amount of calcium while potassium and sodium were high in the seed. It can therefore be deduced that ASA has a great potential in contributing to the healthy growth and as supplementation in food industries.

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