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NUTRITIONAL COMPOSITION AND MICROBIAL QUALITY OF SOME UNDERUTILIZED EDIBLE FRUITS GROWING IN SOUTHWEST NIGERIA

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ABSTRACT This study examined the moisture, ash, fat, crude fibre, crude protein, carbohydrate, energy value, minerals, vitamins, anti-nutrients and shelf-life of four underutilized fruits: ackee (*Blighia sapida*), Cashew Apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*) growing in Southwest Nigeria. The presence of essential minerals such as Na, K, Mg, Ca, Fe, Cu, Mn, Zn and phosphorus was confirmed in all the fruits. However, *I. garbonensis* had the highest concentrations of Na (120.03 mg/100 g), K (80.32 mg/100 g), Ca (148.5 mg/100 g), Fe (3.42 mg/100 g), Cu (2.03 mg/100 g), Mn (1.56 mg/100 g) and Zn (2.43 mg/100 g).The vitamin and antinutrient contents ranged between 30.6-420.34 mg/g and 0.35–25.78 mg/g indicating that the fruits contain low levels of antinutrients considered to have harmful effect on human health. The highest microbial count was recorded in *A. occidentale* within five and ten days of storage. The nutritional contents of the fruits showed that they contained appreciable quantities of all the nutrients studied and could contribute to the nutrient requirements of humans.

Keyword**:** Underutilized fruits, nutritional, minerals, phytochemical, antinutrients, microbial

INTRODUCTION

The consumption of fruit is crucial to the availability of micronutrients to the human body (Banwat *et al*., 2012). This is because they are rich sources of vitamins and minerals required for the normal functioning of the human body. Although required in small quantities, both vitamins and minerals are essential part of the daily diet as the body cannot synthesize them in sufficient quantities to meet the nutritionally recommended quantities (Banwat *et al*., 2012; Silva *et al*., 2017). Fruits are called protective foods as they contain adequate quantity of vitamins, phytochemicals and minerals which help us to keep our body healthy by regulating body processes and helping the body to produce substances which would fight against the disease causing agents (Yahia *et al*., 2019). Apart from the micronutrients provided, fruits contain both soluble and insoluble dietary fiber which reduces the body fat and cholesterol levels from the body and also helps in smooth bowel movements (Singh *et al*., 2019). Fruits also contain high amount of anti-oxidants which help in the removal of free radicals from the body, and therefore provide protection against numerous infectious diseases (Silva *et al*., 2017; Singh *et al*., 2019).

African countries including Nigeria are richly blessed with a lot of fruit bearing species, which yields domesticated and wild fruits (Banwat *et al*., 2012; Silva *et al*., 2017; Umerah and Nnam, 2019). However, it is disappointing that many Nigerians do not eat enough fruits to make them healthy. Recent research studies by Umerah and Nnam, (2019) showed that poor intake of fruits are among the dietary habits of Nigerians. Nigerians especially the rural people have a poor dietary habit of eating late supper, and excessive consumption of starchy crops which impose micronutrient and protein malnutrition. According to the WHO nutritional recommendation, each person should have a daily intake of more than 400 g of fruits such as apples to protect themselves against diet-related infections (Silva *et al*., 2017; Olatona *et al*., 2018). Since low intake of fruits contribute to millions of death yearly from severe diseases world-wide, numerous reasons have been given to be responsible for the low consumption of fruits, some of which include neglect, inability to afford them, seasonal occurrences of fruits all year round and unawareness (Bvenura and Sivakumar, 2017; Silva *et al*., 2017; Umerah and Nnam, 2019). Unawareness and neglect account for low fruit intake in Nigeria where different varieties of fruits are available all year round. Some fruits are just tagged as fruits for poor people (Umerah and Nnam, 2019), and are therefore deliberately

disregarded or considered as unimportant. Also some fruits are just neglected because of cultural believes. Lack of adequate knowledge of the nutritional value and health benefits of some fruits make some people disregard them (Umerah and Nnam, 2019). This may not be different in the case of Nigeria following recent research studies giving evidences of nutrient deficiencies, despite the availability of domesticated and wild fruits in different parts of the country especially the southwestern parts (Umerah and Nnam, 2019).

Since ancient days, edible fruits have played significant role in supplementing the diet of Nigerians and people from other countries (Aworh, 2015). With the problem of malnutrition, fruits are widely accepted as a good and important source of nutrients and supplement for food. They are very important portion of an adequate diet and they serve as food supplement, and an appetizer (Sudhakaran and Nair, 2016).''Underutilized edible fruit" refer to fruits which are neither grown commercially on large scale nor traded widely. These are fruits which are mainly cultivated in localized areas mainly for trade and consumption (Nandal and Bhardwaj, 2014). Also they are fruit crops which are neglected by both the agricultural research centers and development agencies. Underutilized fruit can grow easily under very harsh soil and climatic conditions (Singh *et al*., 2019)

Apart from the use of fruits as food, edible fruits have numerous health benefits as it gives immunity to many diseases. Recent studies have proven that eating a diet high in fruits can reduce a person's risk of developing multiple disorders such as kwashiorkor, cancer, inflammation, heart disease, anemia, urinary tract disorders, diabetes, night blindness, digestive problems among others due to their high rich fiber contents and health boosting anti-oxidants like flavonoids (Sudhakaran and Nair, 2016; Yahia *et al*., 2019; Singh, *et al*., 2019; Achaglinkame *et al*., 2019). Therefore, exploitation of underutilized edible fruits the problem of health and food insecurity in developing countries can be solved by motivating people living in the rural areas to increase their daily consumption of indigenous fruits and food supplements rich in fruits to meet up with their nutritional requirements. Some of the underutilized indigenous fruits in Nigeria that will be assessed are ackee (*Blighia sapida*), Cashew Apple (*Anarcadium occidentale*) and African garden egg (*Solanum melongena*) and African bush mango (*Irvingia gabonensis*).

Ackee is a plant that produces fruits. Ackee (*Blighia sapida*) is a member of the *Sapindaceae* family (Olawale *et al*., 2016). It is also known as anke and akye-fufuo in West Africa where it is commonly available. In Southwest Nigeria, it is called "Isin". Ackee tree is ever green, with a short trunk and dense crown (Olawale *et al*., 2016). The leaves of ackee are paripinnately and long with elliptical leathery leaflets. The inflorescences are sweet-scented with flowers that blossom during summer (Olawale *et al*., 2016). Ackee (*B. sapida*) fruit is pear-shaped (Emanuel and Benkeblia, 2011). The tree produces fruits throughout the year with peak production from January to March and October to November (Emanuel and Benkeblia, 2011). Ripe ackee (*B. sapida*) fruit is eaten as food and is considered a dietary staple in Jamaica. However, unripe ackee fruit is very poisonous. In African traditional medicine, the bark pulp of the tree is used as a liniment for oedema pains in West African countries including Ivory Coast, Cameroon, Ghana and Senegal (Onuekwusi *et al*., 2014).

Cashew, (*Anacardium occidentale*), is an evergreen tropical shrub. Cashew tree produces very soft, shiny, juicy and succulent fruits called cashew apple which bears a single seeded nut covered with a hard gray shell (Pascal *et al*., 2018). This means cashew trees produces cashew seeds and apples (Pascal *et al*., 2018). Cashew tree is about 46ft tall (Aliyu and Awopetu, 2007). Cashew tree is propagated widely because of its nuts in areas of Africa particularly Nigeria, India, Tanzania, Vietnam, Madagascar, Asia and Philippines and Sri-Lanka (Azam-Ali and Judge, 2001; Akinhanmi and Akintokun, 2008). Cashew nut is rich in oil and fat and is commonly used in food preparations. Cashew apple can be eaten fresh, fermented to produce vinegar, cooked in curries and used to produce alcoholic and nonalcoholic beverages (Lowor and Agyente-Badu, 2009; Aremu *et al*., 2006). Cashew apple is a valuable source of sugar, minerals, and vitamins especially vitamin C (Aremu *et al*., 2006; Lowor and Agyente-Badu, 2009; Deenanath *et al*., 2015; Nwosu *et al*., 2016; Pascal *et al*., 2018; Salehi *et al*., 2020). Cashew apples also have medicinal uses.

African bush mango (*Irvinia gabonensis*) is a species of African trees in the genus *Irvingia* (Ogunsina *et al*., 2012). African bush mango trees are evergreen, large and approximately 50 m high. The trees are widely distributed in humid forest zones of West and Central Africa including Ghana, Nigeria, Southern Cameroon and Congo (Ogunsina *et al*., 2012). The tree produces mango-like fruits with flesh that can either be edible pleasant and sweet or bitter and inedible. The common names of edible *Irvingia gabonensis* include wild mango, African mango, bush mango, dika and oro in Nigeria (Onimawo *et al*., 2003; Ogunsina *et al*., 2012). The mango-like fruits are produced in two fruiting

seasons, April to July and September to October. The bush mango fruits are processed into jelly, jam and juice while the seeds are either eaten raw or roasted (Onimawo *et al*., 2003). The seeds and fruit of African bush mango contain a variety of vitamins and minerals including calcium, magnesium, potassium, sodium, phosphorus, and iron (Olanrewaju *et al*., 2020). The leaf, bark, and root extracts of African bush mango has both antifungal and antibacterial compounds such as terpenoids and ellagic compounds which are able to disrupt bacterial and fungal cell membranes, preventing their adhesion and inactivating enzymes (Olanrewaju *et al*., 2020; Arogba and Omede, 2012).

African garden eggplant (*Solanum* spp) belong to the family of *Solanacea* and genus *Solanum* with over 1000 species cultivated in tropical regions like West Africa and South America mainly Brazil and in other countries like France and Italy (Eze and Kanu, 2014). In Nigeria, there are over 25 known *Solanum* species including those domesticated and wild (Eze and Kanu, 2014). Among these species is *Solanum aethiopicum L*. known as the African eggplant or Bitter garden egg (*Solanum aethiopicum*). Bitter garden egg is a delicate perennial fruit often cultivated as an annual crop. It is a shrub that grows up to 3 m height with leaves that are simple, ovate and elliptic (Chinedu *et al*., 2011). In Nigeria, African garden eggplant is commonly called afufa in Igbo, Dauta in Hausa, Igbagba in Yoruba and is consumed daily by the rural and urban people. African garden eggplant is either eaten raw or cooked as vegetables (Chinedu *et al*., 2011; Eze and Kanu, 2014). African garden eggplant is rich in fiber, vitamins and phytochemicals such as phenols and alkaloids (Auta and Ali, 2011; Eze and Kanu, 2014).

Literature search has shown that the fruits of the underutilized fruits; ackee (*Blighia sapida*), Cashew Apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*) have been characterized in some states in Nigeria. Research studies have provided some promising nutritional information of one or more of these fruits. However, most information has been on different species and parts of the fruits selected in this study. While all the nutritional data from previous studies are relevant, information on these Southwest underutilized fruits are lacking. Therefore, the main aim of this research is to determine the nutritional composition and microbial quality of fruits of ackee (*Blighia sapida*), cashew apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*).

MATERIALS AND METHODS

MATERIALS

SOURCE OF FRUITS AND IDENTIFICATION

Matured, fully ripe healthy ackee (*Blighia sapida*), cashew apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*) fruits were purchased from Mile 12 market in Lagos, Southwest Nigeria. The fruits were transported to the laboratory in separate polythene bags. The fruits (Table 1) were identified and authenticated by a taxonomist in the Department of Biological Sciences of Olabisi Onabanjo University, Ago-Iwoye, Ogun State.

SAMPLE PREPARATION AND PROCESSING

The fruits of ackee (*Blighia sapida*), cashew apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*) were sorted and washed in cold distilled water to remove dirt adhering to the surface. The fruits were placed on clean filter papers in the laboratory to dry at room temperature. The husk and black seeds in ackee were removed to obtain the edible arils/pulp. The pulp of cashew apple and African bush mango was detached from the kernel nuts. Garden egg was only cut into parts to dry. The pulps were then sundried in shade for 14 days (two weeks), milled using Marlex Excella mixer/grinding machine (Amazon, UK) and packed in air tight containers and transparent white containers and kept in the refrigerator at 4°C for further processing for analysis.

DETERMINATION OF NUTRITIONAL COMPOSITION OF FRUIT

PROXIMATE COMPOSITION

The proximate composition of the samples was carried out using standard analytical methods described by Neji and Agwupuye, (2019) and AOAC, (2000).

DETERMINATION OF MINERAL COMPOSITION

SAMPLE PREPARATION

Five grams (5 g) of each sample already pulverized was accurately weighed in a porcelain crucible that has been ignited and tarred. The crucibles with the samples were placed in drying oven at 100^{o}C for 24 hours. Thereafter, the crucibles were then dry-ashed in a cool muffle furnace at 550^{o}C for 6 hours. The resulting ash samples were cooled in a desiccator and weighed. Each ash sample was then dissolved in 2 mL of 50 % HCl and 2 mL of 50 % HNO_3 (A 1:1 ratio of solvents)

and allowed to boil for 1 min. This was done by placing the solutions in boiling water bath and evaporated almost to dryness. After boiling, the mixtures were allowed to cool, filtered through Whatman No.42 filter paper into separate 100 mL volumetric flasks and diluted to required volume with deionized water (dH_2O). Each of the solution was well mixed and the minerals were determined from the resulting ash solutions. Blank solutions were also prepared using similar experimental procedure (AOAC, 2005).

DETERMINATION OF IRON (FE), COPPER (CU), ZINC (ZN), MANGANESE (MN), MAGNESIUM (MG) AND CALCIUM (CA)

Atomic absorption spectrophotometer (AAS) (model: 210VGP, Buck Scientific, USA) was used to determine the contents of iron, copper, zinc, manganese, magnesium and calcium in the pulverized fruit samples. Different electrode lamps were used for each mineral. 100 mL were used as the dilution factor for all minerals except Mg. For determination of Mg, further dilution of the original solution was done by using 1 mL original solution and enough deionized water was added to it to make the volume up to 100 mL. For determination of Ca, 1 mL lithium oxide solution was added to the original solution to unmask Ca from Mg. The concentration of each mineral (ppm) was recorded and the total mineral concentration in mg/100 g was calculated using the following equation:

$$\text{Total Mineral Concentration (mg/100g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor} \times 100}{\text{Wt. of Sample} \times 1000}$$

DETERMINATION OF SODIUM (NA) AND POTASSIUM (K)

Na and K analysis of the fruit samples were done using a flame photometer (Jenway PFP7 model). A Flame Photometry method was used. Na and K contents of the samples were determined by using the ash solutions as used in AAS. Standard curves were plotted using standard solutions of NaCl and KCl with concentrations of 20, 40, 60, 80 and 100 ppm. The concentrations of Na or K in the ash solutions were determined from the corresponding standard curve. The concentration of each mineral (ppm) was recorded and the total mineral concentration in mg/100 g was calculated:

$$\text{Total Mineral Concentration (mg/100g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor} \times 100}{\text{Wt. of Sample} \times 1000}$$

DETERMINATION OF PHOSPHORUS (P)

Phosphorus content of each fruit sample was determined using a spectrophotometer. For Phosphorus (P) determination, 22.5g of aqueous ammonium heptamolybate (NH4)6Mo7O2.4H2O) was dissolved in 400 mL of deionized water to make the first solution A. The second solution, B was prepared by dissolving 1.25 g of ammonium vanadate in 300 mL of boiling deionized water. Both solutions were thereafter added together and allowed to cool to room temperature, after which 250ml of concentrated HNO3 was added and the mixture was diluted to 1 L to obtain the colour reagent. For each sample, One milliliter of each ashed solution was taken and 4 mL deionized water added in a beaker. 5 mL of the colour reagent was added to this volume and the total volume of the final solution was made up to 25 mL. After sometime the colour of the solutions turned yellow. Absorbance of the yellow solutions of each sample was read on the spectrophotometer. The absorbance readings from the spectrophotometer were plotted on a standard curve to determine the phosphorus concentration (ppm). Total phosphorus concentration in mg/100 g was calculated using as follows:

$$\text{Total Phosphorus Concentration (mg/100g)} = \frac{\text{Concentration (ppm)} \times \text{Dilution factor} \times 100}{\text{Wt. of Sample} \times 1000}$$

DETERMINATION OF ANTI-NUTRIENT CONTENTS

PHYTATE DETERMINATION

The procedure described by Essien and Akpan, (2014) was used to determine the phytate content in each fruit. Phytate was extracted and precipitated from each fruit sample. This was done by weighing 2g of each pulverized sample into a 250 mL conical flask. 100 mL of 2% concentrated HCl was added to soak the samples for about 3 h. Samples were thereafter filtered using Whatman No.42 filter paper. 50 mL of each resultant filtrate was then placed in a 250 mL beaker and 107 mL distilled water was added to improve acidity. Then 10 mL of 0.3% ammonium thiocyanate solution was added to each sample solution as indicator and titrated with standard iron chloride solution which contained 0.00195 g iron/mL to give brownish-yellow colouration that persisted for 10 min. The percentage phytic acid was calculated.

OXALATES DETERMINATION

The oxalates content of the samples was determined using titration method described by Essien and Akpan, (2014). 2 g of each sample was placed in separate 250 mL volumetric flasks and distilled water (190 mL) was added for soluble oxalate determination. 6 M HCl solutions (190 mL) were also added for total oxalate determination. All the suspensions were digested at 100ºC for 1h. Samples were left to cool at room temperature and filtered. Triplicate portions of the filtrate (50 mL) each were measured into beaker and four drops of methyl red indicator was added, and drop wise addition of concentrated NH_4OH solution (drop wise) was done until the solution changed from pink to yellow. After this, each portion was then heated to 90ºC cooled and filtered to remove the precipitate containing ferrous ion. The filtrates were again heated to 90ºC and 10 mL of 5% CaCl2 solution was added and each stirred continuously. Samples were thereafter cooled and left overnight. The sample solutions were then centrifuged at 2500 rpm for 5 min and supernatant were decanted and the precipitates completely dissolved in 10 mL 20% H_2SO_4. The final filtrates obtained from the digestion of 2g of each sample were made up to 200 mL. Out of this total, 125 mL aliquots of each filtrate were heated and then titrated against 0.05 M standardized $KMnO_4$ solution to a pink colour which persisted for 40 sec. The oxalate contents of each sample were calculated. All determinations were performed in triplicates and results presented in mg/100g.

MICROBIAL ANALYSIS
SHELF LIFE STUDY OF FRUIT SAMPLES

The shelf life study on ackee (*Blighia sapida*), cashew apple (*Anarcadium occidentale*), African garden egg (*Solanum aethiopicum*) and African bush mango (*Irvingia gabonensis*) was determined by monitoring the microbial load of the fruits stored at room temperature (25ºC-30 ºC). Shelf life study was carried out using the pour plate method described by Ogwu *et al*., (2016). For enumeration of microorganisms present in each fruit sample, 10-fold serial dilutions of each rinse water were made and 1 ml of 10^3, 10^6, 10^8, 10^{11} dilutions were pipetted into sterile petri-dishes and molten nutrient agar (45ºC) was added and swirled thoroughly to allow even distribution. The plates were allowed to solidify and kept in the incubator for 24 h incubation at 37ºC. The colonies were then counted using a colony counter (Stuart Scientific, UK) after 24 h incubation. Microbial counts were taken at an interval of five days.

STATISTICAL ANALYSIS

The data obtained in the analysis were subjected to Analysis of Variance (ANOVA) and the means were separated using Duncan multiple range test.

RESULTS AND DISCUSSION

PROXIMATE COMPOSITION

Moisture content varied between 3.90 % to 92.6 % in *B. sapida* and *A. occidentale* respectively. The highest moisture content was observed in *A. occidentale* while *B. sapida* recorded the lowest moisture content (Table 2). The moisture content obtained for *B. sapida* (3.90 %), *S. aethiopicum* (6.20 %) and *I. garbonensis* (4.63 %) in this study are very low compared to 90.0%, 36.1%, 95.3 % and 87.3 % reported by Bala and Bashar, (2017) for mango, guava, watermelon and orange which are locally consumed fruits. The moisture content values for *B. sapida*, *S. aethiopicum* and *I. garbonensis* does not also fall within the limits of 80 - 85 % recorded by some other researchers as acceptable limits for fruits (Eze and Kanu, 2017). However, the low moisture content recorded for *B. sapida* in this study seem to correlate with 3.94% reported by Oyeleke *et al*., (2013). The value of 3.90 % is also lower to 7.25 reported by Adepojuwa *et al*., (2013). Overall, the moisture content of *B. sapida*, *S. aethiopicum* and *I. garbonensis* which are low still falls within the acceptable limit expected of edible fruits and nuts (Ozcan, 2009). It is used as an index of stability and susceptibility of the fruits to fungal and microbial contamination. It also indicates the freshness, quality and shelf-life of the fruits (Poopola and Yangomodou, 2006; Oyeleke *et al*., 2013; Eze and Kanu, 2017). Hence, the relatively lower moisture contents in *B. sapida*, *S. aethiopicum* and *I. garbonensis* suggest longer storability if left unprocessed within a reasonable period of time, hence a need for processing into more stable products (Achaglinkame *et al*., 2019). *A. occidentale* with high moisture content may have a faster tendency to get spoilt since moisture is a basic requirement for microbial contamination of any food (Poopola and Yangomodou, 2006).

Protein content averagely varied between 0.18 % to 15.98 % in *A. occidentale* and *B. sapida*. Likewise all the fruit samples studied have been shown to contain appreciate amount of protein. *B. sapida* recorded the highest protein content (15.98 %) followed by *I. garbonensis* (7.82 %) and *S. aethiopicum* (4.51 %) whereas *A. occidentale* has the lowest crude protein content (0.18 %). According to Kanu *et al*., (2015) any plant food that provides more than 12% of its energy from protein is considered a good source of protein. Therefore, the protein content of *B. sapida* as recorded

in this study meets this requirement and as such is considered a rich source of protein. The protein value obtained for *B. sapida* correlates with 15.27 % and 11.99 % reported by Howele *et al*., (2010) and Oyeleke *et al*., (2013). Fruits are not generally known to contain much protein, but they are essential because they are enzyme catalysts that catalyze many chemical reactions (Eze and Kanu, 2017). Therefore, the protein contents of *S. aethiopicum*, *I. garbonensis* and *A. occidentale* recorded in this study though low still fall within the expected protein content for fruits. The protein contents of *S. aethiopicum* (4.51%) and *I. garbonensis* (7.82 %) correlates with 4.2 % and 7.90 % reported by Eze and Kanu, (2017) and Oyedele and Fatoki, (2017). With these inherent protein values, these fruits may be able to contribute to the daily protein requirement of humans.

Carbohydrate content of all the fruits averagely varied between 7.90 % to 96.78 % in *B. sapida* and *A. occidentale*. Carbohydrates are essential due to their nutrition and metabolic functions (Ahmed and Birnin Yauri, 2008). Carbohydrate content in *A. occidentale* is high (98.83 %) and this correlate with 98.83 % reported by Ahmad and Birnin-Yauri, (2008). This means that *A. occidentale* and *S. aethiopicum* with (24.6 %) are rich sources of carbohydrate and have great potential to supply the human body with good amounts of energy. With this high values, both fruits meet up with the daily 27–59% of the recommended dietary allowance (RDA) of carbohydrate (130–210 g/day) for all age groups (Achaglinkame *et al*., 2019). The value obtained for *I. garbonensis* is low (11.76 %) lower than 18.67 % cited by Ogunsina *et al*., (2012). Also, *B. sapida* contains low quantity (7.90 %) of carbohydrate and is similar to 6.86 % reported by Oyeleke *et al*., (2013).

Fat serves structural and metabolic functions such as energy production and cell function (Ogunsina *et al*., 2012). The fat content of the fruits in this study varied between 0.45 % to 64.70 % in *A. occidentale* and *I. garbonensis*. The result revealed that *I. garbonensis*, *B. sapida* and *S. aethiopicum* are essentially rich sources of fat with 64.70 %, 53.22 % and 39.0 % while *A. occidentale* is a poor source of fat (0.45 %). The fat content of *A. occidentale* (0.45 %) is similar to 0.50 % reported by Ahmad and Birnin-Yauri, (2008). That of *I. garbonensis* (64.70 %) correlates with 67.0 % reported by Ogunsina *et al*., (2012). *S. aethiopicum* and *B. sapida* fat contents of (39.0 %) and (53.22 %) corresponds to the report of Eze and Kanu, (2017) and Oyeleke *et al*., (2013). Low fat value in *A. occidentale* could mean that the fruit may play critical role in preventing heart problem in humans. Nevertheless, the relatively high fat content recorded in *I. garbonensis*, *B. sapida* and *S. aethiopicum* most likely provide a feeling of satiety and reduces hunger (Achaglinkame *et al*., 2019).

The crude fiber content in the range of 2.00 % to 23.5 % was recorded in *B. sapida* and *S. aethiopicum*. This amount of fiber in the fruits could be of great help in aiding the digestive process of humans. The ash content of the fruits, which ranged from 0.53 % in *A. occidentale* to 12.9 % in *S. aethiopicum*, shows their mineral level, and therefore when consumed by humans could help in curbing micronutrient deficiencies in human. The ash content obtained for *A. occidentale* is similar to the 0.50 % reported by Ahmed and Birnin Yauri, (2008). *S. aethiopicum* ash content of 12.9 % is less than the 15 % reported by (Eze and Kanu, 2017). The ash value of *B. sapida* 6.78 % is similar to 6.20 % reported by Oyeleke *et al*., (2013). This value is greater than 1.30 %, 1.28 % and 1.22 % reported by Olawale *et al*., (2016) for *B. sapida* in savannah zones in south west.

The energy content (kcal) of the fruits in this study was observed to increase with their fat contents, ranging from 185.28 in *A. occidentale* to 288.32 in *I. garbonensis* This suggests the fruits could supply approximately 9–19% of the energy (1071–3152 kcal/day) requirement of the human body when consumed.

MINERAL COMPOSITION

The mineral content (mg/100g) of edible portion of the underutilized fruits is shown in Table 3. The Na, K, Mg, Ca, Fe, Cu, Mn, Zn and phosphorus contents of the fruits were established. The results revealed that Na, K, Mg, Ca, Fe, Cu, Mn, Zn and phosphorus contents of *B. sapida* were 28.79, 29.21, 20.65, 26.31, 2.00, 0.10, 0.15, 0.08 and 156.4 mg/100 g. The mineral contents in *A. occidentale* were 26.70, 398.90, 4.90, 1.87, 0.53, 0.09, 0.10, 0.05 and 50.21 mg/100 g. The mineral content of *S. aethiopicum* was 0.58, 4.78, 2.62, 0.13, 0.69, 0.42, 0.62, 0.21 and 13.45 mg/100 g and *I. garbonensis* was 120.03, 80.32, 15.6, 148.5, 3.42, 2.03, 1.56, 2.43 and 9.34 mg/100 g.

Generally, it could be observed that the fruits studied have relatively high concentrations of the minerals analyzed in this study (Table 3). The concentration of Na ranged from 0.58 mg/100 g in *S. aethiopicum* to 120.03 mg/100 g in *I. garbonensis*. Na plays crucial role in keeping the body fluid and electrolytes balanced as well maintain the nerve and muscle functions (Farquhar *et al*., 2015).

Calcium plays a vital role in human body. Calcium is needed for the formation of strong bones and teeth, the regulation of muscle movements, blood clotting, nerve impulse and transmission, regulating heart beat and fluid balance within cells. Therefore, its presence in human diets is very essential (Flynn, 2003).

Potassium concentration in the fruits varied averagely from 4.78 mg/100 g in *S. aethiopicum* to 398.90 in *A. occidentale*. There was significant difference in the potassium concentration of the fruits ($p > 0.05$). According to He and MacGregor, (2008) and Achaglinkame *et al*., (2019) potassium plays a very vital role in the body by helping the body maintain its fluid, osmotic balance and regulating both the nerves signals and muscle contractions.

The magnesium values, on the other hand, ranged significantly ($p < 0.05$) from 2.62 mg/100 g in *S. aethiopicum* to 20.65 mg/100 g in *B. sapida*. Magnesium is needed for a many biochemical reactions in the body. It helps to maintain normal nerve and muscle function, keeps the bones strong, heart beat steady, adjust glucose levels and supports healthy immunity (Laires *et al*., 2004). Its deficiency has been linked with very serious health issues such as hypertension, stroke, severe diarrhea, and migraines (Laires *et al*., 2004).

A range of 0.09 mg/100 g in *A. occidentale* to 2.03 mg/100 g in *I. garbonensis* of copper was observed among the fruits, with not much significant variation ($p < 0.05$) from the other. It has been established that copper is a mineral and an essential nutrient needed by the body. Together with iron, copper helps the body to form red blood cells. It contributes to iron absorption as well as well as helping in maintain healthy bones, blood vessels, nerves, and immune function (Bost *et al*., 2016). Its adequate consumption in food helps prevent heart disease and osteoporosis (Bost *et al*., 2016). Its deficiency has been linked with vision loss, frequent sickness, celiac disease, loss of memory and brittle bones (Bost *et al*., 2016).

For manganese content, *I. garbonensis* recorded the highest value (1.56 mg/100 g), while *A. occidentale* recorded the lowest (0.10 mg/100 g). Manganese contributes to many bodily functions including the metabolism of amino acids, cholesterol, glucose, and carbohydrates. It is also essential in bone formation, blood clotting, and reducing inflammation (Finley *et al*., 2003).

Zinc varied significantly from 0.05 mg/100 g in *B. sapida* to 2.43 mg/100 g in *I. garbonensis*. Zinc is linked with protein synthesis, the catalytic activity of several enzymes, rapid growth and development during child growth and wound healing process (Roohani *et al*., 2013).

The amount of phosphorus in the fruits varies. Phosphorus values, ranged significantly ($p < 0.05$) from 9.34 mg/100 g in *I. garbonensis* to 156.4 mg/100 g in *B. sapida*. Phosphorus plays key role in the formation of strong bones, teeth, muscle contraction, and the maintenance of a regular heartbeat. Ingestion of high amount of phosphorus is harmful to the kidneys, bones and blood vessels (Roohani *et al*., 2013).

VITAMINS AND ANTINUTRIENT CONTENT

The vitamin content and anti-nutrient contents (mg/100g) of edible portion of the underutilized fruits are shown in Table 4. The vitamin C content of the fruits was 30.6, 50.21, 420.34 g, and 79.09 for *B. sapida*, *A. occidentale*, *S. aethiopicum* and *I. gabonensis.* Phytate contents in *B. sapida*, *A. occidentale*, *S. aethiopicum* and *I. gabonensis* were 3.68, 1.67, 10.98 and 0.78 while oxalate contents were 2.01, 1.03, 25.78 and 0.35.

The vitamin C content (mg/100 g) varied significantly from 30.6 mg/100 g in *B. sapida* to 420.34 mg/100 g in *S. aethiopicum*. This vitamin is a very important antioxidant that enhances non-heme iron transport and absorption and the reduction of folic acid. It also play key role in the synthesis of connective tissues as well as collagen. Lack of Vitamin C in the human body causes fragility of blood capillaries, gum decay and scurvy (Achaglinkame *et al*., 2019).

The anti-nutrient contents (phytates and oxalates) found in varying quantities in *B. sapida*, *A. occidentale* *S. aethiopicum* and *I. gabonensis* whole fruits are presented in Table 4. Anti-nutrients reduce the utilization of essential vitamins, minerals and protein therefore preventing exploitation of the nutrients present in a food. The antinutrients contents of the fruit samples studied differed significantly ($p < 0.05$) (Table 4). The phytate content (mg/g) varied from 0.78 mg/100 g in *I. gabonensis* to 10.98 mg/100 g in *S. aethiopicum*. Phytate is known to reduce digestibility of amino acids as well as hinder the absorption of macro-minerals such as magnesium, phosphorus, iron, calcium, and zinc by forming complexes with them. Thus this makes these minerals not readily available to the body. The phytate values obtained in this study were lower than the 10–60 mg/100 g reported to cause problem of mineral bioavailability (Olaniyii and Rufai, 2020). This suggests that the fruits may not cause any mineral absorption problems if consumed.

Despite the negative impact of phytate on human health, phytate has antioxidant and anticancer potentials. Oxalate content varied from 0.35 mg/100 g in *I. gabonensis* to 25.78 mg/100 g in *S. aethiopicum*. When oxalate is present in higher concentration 45 mg/100 g in foods, it inhibits renal calcium absorption (Olaniyii and Rufai, 2020). Therefore, the values obtained for the fruits samples studied are far less than the value considered to have harmful effect on human health. The observed content of phytate (10.98 mg/100 g) and oxalate (25.78 mg/100 g) in *S. aethiopicum* does not correlate to that of Benjamin *et al*., (2020) who reported much higher values of 17.01 mg/100 g and 38.37mg/100 g.

SHELF LIFE OF FRUIT SAMPLES

The shelf life of edible portion of the four underutilized fruits is shown in Table 5. The microbial count of the fruits was monitored and expressed in colony forming unit per gram (cfu/g). *I. gabonensis* and *B. sapida* fruit samples had the lowest microbial counts at one to five days of storage followed by *S. aethiopicum. A. occidentale* had the highest microbial counts.

Microorganisms constitute a major mechanism by which many foods especially fresh ones lose their quality. The shelf life was determined by storing the fruit sample at a temperature of 25°C-30°C for fifteen days when the physical appearance of the fruits does not look good for consumption. The microbial load of the fruit samples was used to determine the shelf-life of the sample. The shelf life of the fruits was shown to be at five and ten days when the microbial load was determined to be within the limit of Specific Spoilage Organisms (SSO) counts of 10^3-10^8 cfu/g. The limit of microbial growth that determines shelf-life differs according to the type of food and storage conditions. Specific Spoilage Organisms counts from 10^5-10^8 cfu/g are considered as safest quality limits for food consumption (Odeyemi *et al*., 2020).

CONCLUSIONS

The study revealed that *B. sapida, A. occidentale, S. aethiopicum* and *I. garbonensis* are good sources of nutrients, mineral, vitamin/anti-nutrients that are beneficial to the human body. The study reveals that the fruits can contribute to the daily nutrient requirements in humans. The antinutrient contents of the fruits were relatively low, and may not pose any serious health problems in humans. This study clearly shows that *B. sapida, A. occidentale* and *I. garbonensis* contains higher amounts of nutrients and minerals while *S. aethiopicum* contained the highest amount of vitamins and anti-nutrients. Therefore, with the nutritional and antinutritional information provided in this study, it is evident that these edible fruits, which lack popularity or recognition, public patronage and consumption in the Nigerian community despite their availability, could help curb the menace of hunger, malnutrition and some nutrient deficiencies. However, due to the perishability of the fruits, it would be very proper to convert them into fruit juices and snacks such as cookies to ensure extended consumption.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest report in this work.

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Table 1. Botanical names, pictures of the fruit samples used for the study.

Fruit name	Botanical name of fruit /plant	Picture of matured fruits	Pictures of fully ripened fruits
Ackee	 *Blighia sapida*	 Ackee is yellow in colour when unripe	 Ackee is pink in colour when ripe
African bush mango	 *Irvingia gabonensis*	 African bush mango is green in colour when unripe	 African bush mango is orange in colour when ripe
Cashew apple	 *Anacardium occidentale*	 Cashew apple when not fully ripe	 Cashew apple is fully ripe
African eggplant	 *Solanum aethiopicum*	 African eggplant is green when unripe	 African eggplant is fully ripe

Table 2.The proximate composition of four underutilized edible fruits

	Fruit samples			
Parameters	***B. sapida***	***A. occidentale***	***S.aethiopicum***	***I. gabonensis***
Moisture (%)	3.90 ± 0.03^{a}	92.6 ± 0.67^{b}	6.20 ± 0.03^{c}	4.63 ± 0.07^{d}
Carbohydrate (%)	7.90 ± 0.02^{a}	96.78 ± 0.13^{b}	24.6 ± 0.02^{c}	11.76 ± 0.03^{d}
Crude protein (%)	15.98 ± 0.03^{a}	0.18 ± 0.33^{b}	4.51 ± 0.01^{c}	7.82 ± 0.02^{d}
Ash (%)	6.78 ± 0.02^{a}	0.53 ± 0.09^{b}	12.9 ± 0.03^{c}	1.94 ± 0.01^{d}
Fat (%)	53.22 ± 0.03^{a}	0.45 ± 0.10^{b}	39.0 ± 0.03^{c}	64.70 ± 0.04^{d}
Fiber (%)	17.15 ± 0.02^{a}	2.00 ± 0.01^{b}	23.5 ± 0.02^{c}	9.43 ± 0.02^{d}
Energy (kcal)	275.21 ± 1.19^{a}	185.28 ± 1.03^{b}	260.43 ± 1.16^{c}	288.32 ± 1.20^{b}

Values are mean ± standard deviation. Values with different superscripts in the same row are significantly different ($p < 0.05$).

Table 3. Mineral composition (mg/100 g dry weight) of four underutilized edible fruits

	Fruit samples			
Minerals (mg/100g)	***B. sapida***	***A. occidentale***	***S. aethiopicum***	***I. gabonensis***
Na	28.79 ± 1.09^{b}	26.70 ± 2.01^{b}	0.58 ± 0.21^{a}	120.03 ± 1.43^{c}
k	29.21± 1.00^{b}	398.90 ± 8.2^{d}	4.78 ± 1.13^{a}	80.32 ± 1.07^{c}
Mg	20.65± 1.00^{b}	4.90 ± 0.20^{a}	2.62 ± 0.09^{a}	15.6 ± 1.54^{b}
Ca	26.31± 1.21^{b}	1.87 ± 0.35^{c}	0.13 ±0.06^{a}	148.5 ± 1.43^{d}
Fe	2.00 ± 0.09^{c}	0.53 ± 0.20^{a}	0.69 ± 0.23^{a}	3.42 ± 0.32^{b}
Cu	0.10 ± 0.05^{c}	0.09 ± 0.01^{c}	0.42 ± 0.21^{c}	2.03 ± 0.12^{b}
Mn	0.15 ± 0.03^{a}	0.10 ± 0.02^{a}	0.62 ± 0.30^{a}	1.56 ± 0.07^{b}
Zn	0.08 ± 0.02^{a}	0.05 ± 0.03^{a}	0.21 ± 0.08^{a}	2.43 ± 0.09^{b}
Phosphorus	156.4± 0.02^{a}	50.21 ± 2.00^{b}	13.45± 0.10^{c}	9.34 ± 0.21^{d}

Values are mean ± standard deviation of triplicate readings. Values with different superscripts in the same row are significantly different ($p < 0.05$).

Table 4. Vitamins and antinutrient content of four underutilized edible fruits

	Fruit samples			
Nutrients	***B. sapida***	***A. occidentale***	***S. aethiopicum***	***I. gabonensis***
Phytate (mg/100 g)	3.68 ± 0.05^{a}	1.67 ± 0.09^{c}	10.98 ± 1.02^{b}	0.78 ± 0.08^{d}
Oxalate (mg/100 g)	2.01 ± 0.01^{a}	1.03± 0.03^{b}	25.78 ± 0.10^{c}	0.35 ± 0.02^{c}
Vitamin C(mg/100 g)	30.6 ± 0.05^{d}	50.21 ± 0.03^{c}	420.34 ± 1.03^{a}	79.09 ± 0.33^{b}

Values are mean ± standard deviation of triplicate readings. Values with different superscripts in the same row are significantly different ($p < 0.05$)

Table 5. Shelf life monitoring of four underutilized edible fruits stored at 25ºC-30ºC

	Microbial load of fruit samples (cfu/g)			
Time (days)	***B. sapida***	***A. occidentale***	***S. aethiopicum***	***I. gabonensis***
One	$1.0 \times 10^3 \pm 0.05$	$3.0 \times 10^3 \pm 0.07$	$1.2 \times 10^3 \pm 0.07$	$1.0 \times 10^3 \pm 0.05$
Five	$2.2 \times 10^6 \pm 0.06$	$4.9 \times 10^6 \pm 1.05$	$2.9 \times 10^6 \pm 0.08$	$1.9 \times 10^6 \pm 0.09$
Ten	$3.2 \times 10^8 \pm 0.09$	$5.8 \times 10^8 \pm 1.05$	$4.5 \times 10^8 \pm 1.01$	$2.8 \times 10^8 \pm 0.14$
Fifteen	$4.7 \times 10^{11} \pm 1.00$	$6.9 \times 10^{11} \pm 2.05$	$5.4 \times 10^{11} \pm 1.15$	$4.9 \times 10^{11} \pm 1.05$

Values are mean ± standard deviation of triplicate readings